PRACTICAL SHIPBUILDING

A HANDBOOK

OF

PRACTICAL SHIPBUILDING

WITH

A GLOSSARY OF TERMS

BY

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SUPERINTENDENT IN HULL CONSTRUCTION
HOG ISLAND SHIPYARDS
(*American International Shipbuilding Corporation*)

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PREFACE

This handbook on the practical construction of a modern standard cargo steamer has been written in answer to some of the many questions which from time to time have been asked by men who have been working under the supervision of the writer, and is intended to fill the need for a guide to the new men starting in shipyard work.

During many years' experience in shipyards on all types of marine construction from the smallest of torpedo boats of years ago to the mighty war vessels and merchant ships of to-day the writer has been associated with the men who are to-day supervising the wonderful shipbuilding program on which this country is engaged, and he has endeavored to embody the results of this more than twenty years' experience in the book.

In the present struggle on land and sea, when everyone must use all his might, this manual of the necessary steps in fabricating and assembling of vessels has been prepared with the hope that it will prove a help to some of the many thousand men who must come into this industry from other trades.

Team work is necessary in all lines, sports and commercial enterprises alike, but in none is it more essential than in an enterprise where so many different trades are

all working together, and the results of their labor must be co-ordinated to effect a satisfactory conclusion.

The riveters must follow the reamers and the reamers must follow the bolters-up, etc., therefore, it is necessary that all the men working on the ship should have an intelligent understanding of the general plan.

J. D. MACBRIDE.

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CHAPTER I

Shipyard Organization

The shipbuilding business is like any other in that its executive and financial departments are separate from the manufacturing or fabricating branches of the organization. As this volume is not concerned with the Economics of Shipbuilding, but with ship construction, we need not burden ourselves with descriptions of the duties of officials like the President, Treasurer, etc., whose functions do not bring them directly in touch with the actual work of putting a ship together.

In a modern shipyard the General Manager has charge of both Hull and Engine Departments, but he is the only connecting link, the two branches working quite independently of one another.

The Engine Department has a drafting room in which the designs and all detail drawings for use in the yard are made. Much of the work is made up of castings which are shipped in from outside firms according to plans furnished them and the shipyard is interested in making the rough casting over into a finished product ready for in-

stallation in the ship. Nearly all large shipyards have a machine shop with the necessary lathes, planers, shapers, etc., to do the work, with ample overhead crane facilities to handle the heavy weights.

The Machine Shop often has the heavy work on the floor, with galleries above to carry the smaller and lighter weight machines and fittings where much of the "bench work" is done on the small brass castings. When the heavy lathes, planers, etc., are at one end, on the floor, the other end of the building is devoted to erection work. The engine bed is laid down and thoroughly bolted, and the engine then put together piece after piece. This is done to be sure it will fit when carried to the ship, as this assembly work can be done while the ship is still under construction on the shipway. Any necessary changes can be made at this time without delaying delivery of the ship to the owners. After the whole engine has been assembled, it is taken down and sent to the ship as soon as the Engine Room is ready to receive it. This work is done for both reciprocating and turbine engines.

This also applies to such parts as propellers, propeller shafts, thrust blocks, etc. The condensers, auxiliary pumps, and fittings are often bought from an outside firm all ready for installation in the ship.

The Boiler Shop is the other large portion of the Engineering Department and in it the boiler work is all laid out. The equipment of this shop varies with the type of boilers that the shipyard is using, whether "Scotch" or "water-tube" types.

When the "Scotch" boilers are used the heavy boiler

plates are curved to the required circular shape by heavy, upright rolls. These plates are assembled, the furnaces, stay-rods, etc., fitted and after being riveted, caulked and tested with a water-pressure, they are set outside the shop until the Boiler Room is ready for them. " Water-tube " boilers are made up of many small parts and are often put together on the ship for the first time. The parts are light in weight and easily handled.

The Hull Department, has a drafting room separate from that of the Engine Department, in which the hull structure is laid down and detail drawings made of the different parts of the hull, such as shell, deck, and bulkhead plating; also all details for the hull fittings.

Each detail plan of the steel plating of decks, bulkheads, etc., gives all necessary information regarding the thickness of plates, the symbol whereby it may be traced from the Steel Yard, and dimensions giving all sizes. Where special riveting is required this is also shown in detail, but most of it can be described by notes, giving the diameter, spacing and type of head and point.

These plans show where all the angles are placed, all butts in plates and angles and all information necessary for assembling the whole of that part of the ship.

The Steel Yard is the place where the material for the hull is stored until it is ready for use. The various plates being placed together according to their destination on the ship, as shown by the marks painted on them by the steel makers.

All plates are stowed on edge so any of them may be taken out without disturbing all the others. They are

held together and kept from falling by means of a rack which is sufficiently wide for the Yard men to lay the plates over at a small angle so they can look over the plates in order to find the symbols which indicate where it is to go when they are ready to send it to the ship.

The angles and channels are stowed separately and so placed that they can be easily identified when needed.

All material, being heavy, is handled by cranes either over head or of the traveling type.

Bookkeeping for all this material in a large yard is a huge task and must be done carefully or the work of the yard would at once come to a standstill. Each piece of plate or angle must be stowed so it can be located and taken out from a large pile of other steel on a few minutes' notice.

The Mold Loft is a long, narrow room with an exceptionally smooth floor on which the outlines of the various parts of the hull are laid down and drawn full size. Information for this work is supplied in "offset tables" by the Hull Drafting Room.

Mold material is thin wood, about $\frac{1}{8}$ in. thick and about 4 to 6 in. wide which is tacked together to suit the full-sized shape of the plates and on this is marked the exact shape of the plate and the location of all rivet holes. Each mold is marked with the same symbols as the plate and is then sent down to the Shipyard.

When a mold arrives and work is ready to begin on a plate, it is taken from the rack and sent to the ship fitter, somewhere near the ship shed.

Here the ship fitter lays the mold on the plate, marks

off the outline, also each rivet hole. When ordering the plate in the Drafting Room an allowance of 1 in. on the length and ½ in. on the width is added extra on the "dead flat" (perfectly straight and flat) plates, so the fitter has to be careful and be sure that he is quite correct.

From here the plate is carried over to the Ship Shed.

The Ship Shed is generally a large, low shed having the machinery necessary to fabricate the plates for the ship work. The plates are often passed to the rolls for straightening out flat before laying the mold on them. These rolls can be adjusted and, having two on top and three below, can roll a plate quite flat.

If the plate has "sny" or is a rolled plate on the bilge or elsewhere, it is put through the "Bending Rolls" which have one roll above and two below, thus giving a curve to anything which passes in between them.

After the plate has been rolled flat or to the curved surface required, it is carried to the **Shears,** which are large, heavy cutters, sufficiently long to take the length of the average plate at one time, where it is cut to the lines as marked from the mold by the fitter.

The Punch is the next step in the program. The plate is laid on a series of small wheels which are set in a frame, allowing them to face in any direction. These wheels are close up to the punch and the operator on the punch has one man, or more, to assist in pushing the plate in the desired direction. The punch man stands at his machine and moves the plate until the rivet marks, as set off in small circles with white lead, are directly under the punch, when he operates the machine and the

rivet hole is punched out, the "punching" dropping onto the ground to be gathered up later on and sold for scrap.

After the plate has been sheared and punched, if it is to be an "outside" plate it must be countersunk. (Should it be an "inside" plate it is passed right on to the ship.) The **Countersink** is a drill with an entrance of 45 degrees, as a general rule, and it is drilled into the rivet hole until the straight part of the first hole has been cut down to $\frac{1}{16}$ in. in depth. Thus, every countersunk hole should have a straight length and then flare out at the bevel, or angle of the countersink. This is done to be sure that the rivet will "draw" the two plates, or plate and angle, together.

The plate is now ready for the ship.

The Bending Slab for the frames is usually located under the Ship Shed roof, but as it is described under "Frames," nothing else will be said of it here.

The Blacksmith Shop is an important place in the shipyard, as much of the water-tight staples and the deck fittings, such as rail stanchions and boat davits, are produced there. Some yards have an equipment for "drop forgings," as many of the fittings are alike and much time is saved in this way.

The Galvanizing Shop is necessary as much of the material from the Blacksmith Shop has to be galvanized to avoid rust from exposure to salt air and water. This is also true of some of the piping in certain parts of the ship and as much of it has to be bent it is bought black, bent to shape and then galvanized.

The Joiner Shop gets out all the inside wood work for

the ships, such as berths, tables, lockers, etc., in the shop and when the ship is far enough advanced it is then carried out and placed on board. Some pieces which may be too large to pass through openings in the ship are "knocked down" and then put together again in the ship.

The Pilot House is often built in the Joiner Shop and then skidded down to a crane or "shear legs" and lifted aboard and into place on the Bridge.

The Pattern Shop makes all patterns for ship and deck fittings such as hawse pipes (rudder and stern frames are made near the place of manufacture, at the foundry), chocks, bitts, etc. As the deck fittings are of a standard type the patterns for them may be used many times, and such patterns are carefully stored for future use; but hawse pipes have to be made to suit the shape of the bow of the ship and as this is different with each new design they are destroyed after having served their purpose.

Some shipyards have a **Brass Foundry** for casting small deck fittings and others used in the Engine Room, and elsewhere. Steel castings are generally bought from outside firms, which are furnished with the Company's patterns for the work.

The Pipe Shop is one of the important shops in the yard, as it has to furnish all the piping for the Engine and Boiler Rooms, Bilge and Ballast Systems, Fresh Water and Sanitary Piping throughout the ship. This work includes all kinds of pipe fitting, flanged and threaded, in all sizes, of brass, copper, and steel.

This shop also has a department of sheet iron work,

and takes care of all the ventilation piping, cowls on deck, etc. It gets out the material in the shop and has a force on the ship installing it as soon as the ship is in an advanced stage to permit this kind of work.

The Acetylene Department has lightened the labor in recent years in the shipyards as much of the burning out of holes, cutting and trimming of plates, and angle bars, and work of that kind, which took a lot of time, partly because the material had to be brought to the machine which could do it, can now be quickly done by one man. Some yards use it for welding water-tight staples in angle bars, water-tight corners, etc., but not for any part of the structure where strength is required. The Acetylene Department is now a fixture as it has passed the experimental stage on ship work.

The Acetylene Workman generally uses one tank for oxygen about 9 in. diameter and 4 ft. long, and one tank for acetylene about 12 in. diameter and 3 ft. long. The oxygen tank has about 250 cu. ft. and the acetylene tank the same. The operator uses these tanks laying on their sides, hitched together by a Regulator which governs the flow of the gases. Three-eighth inch diameter rubber pipe is used from tanks to the work, in 50-ft. sections, often three 50-ft. pieces being hitched together. For cutting work a straight line and a circle cutter are used. The first can be guided by another plate for a marker and the circle cutter has a beam with a pivot for the center, thus cutting a true circle. Thickness of the material to be cut determines the size of burning "tip." These vary from No. 1 to No. 5 for thin plates up to about 8 in. thick.

The welding is done by the "welding torch," and welding rods. These rods are $\frac{1}{4}$ or $\frac{3}{8}$ in. in diameter and are fused by the heat, so they drop onto the material to be welded, which has become hot, and form a weld. Welding tips vary from No. 1 to No. 12 for light to heavy material to be welded.

Without the **Air Compressor House** a modern shipyard would have to shut down, as a greater part of the work formerly done by hand is now done by an "air machine," whether it is a riveting "gun," a reamer, chipping hammer or any of the many different air tools now so commonly used.

In the "old" days (a few years ago) two men did the riveting together, one man striking the rivet as the other was raising his hammer for the next blow. The "holder-on" would use a heavy hammer to back-up the head of the rivet. Now he has an air machine which he can set against the rivet head, place the leg against a wood backing or other support, and let the machine take the blow from the riveter on the other end of the rivet.

Compressed air is carried all through the yard to the various shipways and shops, in steel pipes placed under ground, and is carried at a high pressure because of the many men using it at the same time.

An hydraulic **riveting machine** often called "the Bull Machine" is installed in a part of the yard which is easily accessible and all the riveting work, such as floors and some foundations, which can be done "snap" (with a "button" point) is done here before sending the material

to the ships. This machine is fixed in a permanent position and the material is handled around it by means of a small, electric crane. In this way much of the steel can be made ready and assembled before the ship is in a condition for it to be installed, thus saving much time credited to construction of the ship.

Directly after launching, the ship is towed to the **Fitting-out Wharf.** Here some means is provided, either with a "shear-legs," or some form of traveling crane, for lifting in the heavy weights, such as engines and boilers, which were not placed before the launching of the ship. A railroad track is carried along the wharf so that much of the material yet to be installed can be sent down and swung aboard.

Shear-legs are two spars, formed of steel plates large at the middle and tapering at the ends which meet at the upper ends and have the bottom ends wide apart. The foot of the spars rest on the edge of the wharf and the tops are tilted out over the water so they will plumb the center line of an ordinary ship, and are held with backstays of steel wire rope. With a "fall" of steel rope and blocks and a winch on the wharf all material can be easily raised from the wharf, swung out over the ship and lowered down on board.

The traveling cranes are usually on a track on the wharf with an arm overhanging the water.

CHAPTER II

Division of Work

The work on the hull of a ship is divided about as follows: **Plate Hangers or Erectors, Ship Fitters, Riveting Department, Ship Carpenters, and Ship Joiners.**

Each of these different trades is separate from the other and has an entirely separate organization. There is one General Foreman in entire charge of a department and he has foremen under him on each boat which is under construction. These foremen in turn may have sub-foremen or " quartermen " in charge of gangs.

Duties of the " Erector " or " Plate Hanger "

This is the man in shipbuilding practice who places the various parts of the ship in their proper positions, after they have been fitted up or fabricated in the shop. The Erector has working with him a number of Bolters and Carpenters who carry on certain parts of the work not conveniently looked after by the Erector himself.

The first job which the Erector has to do is to place the keel in position on the blocks. In doing this work he has the assistance of the yard Riggers and a few Bolters who see that the plates are properly bolted up. The various plates are properly marked according to a particular system, which enables the Erector to put each one in its

proper place, as indicated on the drawing with which he is supplied.

The flat keel plates when deposited on the blocks are trued lengthwise, to the center line of the ship laid on the keel blocks. The center line of the keel is snapped on the keel plates with a chalk line, located from the holes already punched in the plates.

The garboard strakes on port and starboard sides are next placed. Be sure to get the proper lines of rivet holes fair in placing all strakes. It is not necessary to set all keel plates before the garboard and bottom strakes are placed; place a hundred feet of keel, and while continuing work on the keel, more workmen will start the garboard and other bottom strakes, placing alternate port and starboard bottom strakes.

After the bottom of the ship is laid to the turn of the bilge, the Bolters fair the holes, then the center vertical keelson is placed. This sometimes comes from the shop with the angles attached, and the holes punched in them. The holes in these parts must match, and if the keel has not been properly placed, the keelson will not set true fore and aft.

After the keelson is set, the floor plates may be erected. The Erector must be sure that the proper holes are used in bolting up the parts, or the plates will not stand square with the keel. Midship floors are put in place first, so work may proceed fore and aft at the same time.

As each floor is bolted to the vertical keelson, be sure the proper "liner" is in place on the shell, for the outer strake plate. The shell should be bolted, starting

at the garboard strake, as this serves as a guide in fairing other strakes, because it is attached to the keel, and this in turn is attached to the heavy vertical keelson, which holds all parts true.

The tank top is generally a level surface, so the floors are shored up or down by means of shores and wedges, until they are level athwart ships. If slight errors have occurred in the manufacture of the parts, the fairness of the shell should be given preference over the tank top. After the floors are erected and faired, they may be bolted solidly, placing a bolt in every third hole. The intercostal longitudinals may now be set.

As the various parts go up, some men are assigned to "lining" and "packing" work. This work consists of putting "taper" liners at the plate landings of the shell, the "parallel" liners between the frame and the outer strake, and as the vessel progresses, of putting liners at the side strakes, tank top and decks.

Stop waters are also placed at water-tight bulkheads and such other places as the design of the vessel may demand. This work is not looked after by erectors, but by another class of workmen. It is the duty of these men, known as "linermen" and "packers," to see that these details are attended to as the ship advances. After the floors are leveled and the shell faired the tank "margin plate" is put in place.

This serves to fair and hold the ends of the floors in the proper position, and is a base for placing the side frames. It is not necessary that any one of the steps described shall be carried out over the whole bottom

before the next is taken up. The floors amidships may be in place and bolted up, with tank margin plate being bolted while the keel may be going down forward or aft.

The Erector must always be careful to keep his keel true to the line on the blocks, and all holes fairing properly, in order that the ship may be erected true to her designed form.

After the start is made with the margin plate and it is bolted down on port and starboard side by the Erectors, a gang may start reaming the sections that are bolted up. This work is done by the Drillers and Reamers, who ream every hole in which there is not a bolt. A gang of Bolters works with the Reamers, transferring the bolts from the unreamed to the reamed holes. The Reamers going over the berth a second time and reaming the holes from which the bolts were taken.

During this time, Erectors have continued running up the side frames and shell, and started laying the tank top plating. Riveters have started work on all berths that have been prepared by the Reamers, and they proceed with riveting up the bottom shell. The side strakes should not be finally bolted to the frames, till the frames are set up, the deck beams placed, and the "stringer plate" set. The stringer plate on each deck serves to fair the frames. As the deck beams are placed, their midpoints should be checked up directly over the keel and beam stanchions, set and bolted.

As the side frames and deck beams are going up, the transverse bulkheads are set true to the keel, and the deck stringer plates bolted up. After the stringer

plates are set, and the frames fair, the shell plating may be faired and bolted. Deck plating may be placed and reaming done on all parts, as already described. The riveters now drive the class of rivets required by the specifications.

The shell angles or lugs for various deck stringer plates may be fitted and riveted as the hull goes up.

In the case of the side stringer bars, many of them are curved. If the curvature is slight, the bars may be sufficiently flexible to be pulled into position without preliminary bending; if considerable, or if the bars are of rigid section, each one is bent to shape in the shop. Intercostal shell bars are fitted in short lengths between each frame. The shell chocks (short angles) for stringers are placed above the plate, for they are then more easily fitted and riveted; but if, when so placed, they would foul a shell landing, they are fitted below it.

Special bars are used for making bosom pieces (butt-straps on angle bars) having the same thickness as those bars it is intended to connect, but flanges half-inch narrower. To secure proper caulking in bosom pieces of water-tight work, the rounded toe should be removed by planing or chipping. The edge should be sufficiently sharp and square for caulking purposes. The ends of joined bars should be smoothly cut.

The tank margin plates amidships are straight fore-and-aft, but those towards the ends have curved outer edges. In placing deck plating the stringer plates are often the first dealt with, for when they are in place they serve to hold the frames fair and at the proper distance. The

position of the various plate landings is determined by the holes in the plate and on the beams. A working plan is provided for each deck, showing every feature affecting the plating, and giving figured dimensions for all distances and sizes. When the weather deck stringer plates are up in place, the gunwale angle may be fitted.

The necessary information for placing shell plating is provided on an expansion plan of the shell. The position, form, and thickness of all doubling plates and the size and positions of cargo ports, side lights and scuppers, all water-tight bulkheads, tank margins and divisions; the decks, also intercostal stringers, keelsons, bilge keels and fenders is shown. The breadths of the landings, lap joints and buttstraps, size and spacing of the rivets. The different classes of riveting may be shown by marking across them one, two, three, or four short lines. Large-scale sketches are provided to illustrate the method of fitting special parts, such as the disposition of the buttstraps, the rivets in the shear strake joints, and the tack rivets in the doubling; the mounting of cargo ports, etc. It is important that every feature affecting the fitting of the shell plating should be clearly understood, so that no trouble arises as the ship is built.

The parts of a cellular double bottom are differently arranged at various localities; under the engines, for instance, additional intercostals are introduced, and towards the ends the ordinary line of intercostals may step inwards towards the center line. These variations are indicated to the workman on the plans and frame list.

Duties of the Bolter

The work of the Bolter is to bolt the parts of a vessel solidly together after the erector has set them up. He may assist the Erectors or "Linermen" in placing the various liners. The purpose of the liners mentioned will be explained later.

The Bolters need an ample supply of bolts, nuts, washers, and liners. Some bolts are $\frac{1}{8}$ in. smaller in diameter than the holes in the plates, and some are $\frac{1}{4}$ in. smaller. This latter size bolt is necessary for bolting certain plates in which the holes come unfair. The Bolter also needs a "drift" pin, a sledge hammer, and a solid wrench. These tools are necessary for lining up the plates.

In starting a ship the Erectors have with them a number of Bolters, who assist in erecting and put a few bolts in place to hold the parts in the desired positions. They also work with the "Regulator" in lining the various parts of the ship. Following the Regulators and the small squad of Bolters, just mentioned, comes a large gang of Bolters who line up all holes by drifting, and bolt everything solidly for the Reamers. As the Riveter goes over the hull in his work, he removes the bolts and replaces them with rivets. The rivets placed in the holes not bolted hold the parts firmly together as the bolts are removed.

In punching the various parts of a hull in the shops the holes to be riveted are located in the exact position necessary for accurate assembling; but a great many come "unfair" when the ship is erected, and these must

be "drifted." If the hole is "half blind," it must be reamed for a larger rivet.

The Drillers and Reamers attend to reaming the holes in the plates.

Whenever a countersunk hole is enlarged to correct unfairness, the countersink should also be enlarged to accommodate the larger rivet. Small rivets must not be used for riveting up unfair holes.

The Bolters, in clamping up the parts, must see that the irregularities are removed by using a large number of bolts to clamp the plates in place against the frame. When plates are bolted up they must look true and even.

Liners are laid as required, and must be well fitted, by means of a template giving the required lay-out of holes. These liners are made in the smith shop and punched before placing.

The Bolter, in addition to bolting frame, shell, and deck, bolts up the bulkheads. Plates are located in the same manner as described for the shell and deck plating and this work presents no new features.

In setting up his work the Bolter must be sure it is hove up solidly, so the rivet may not spread out between the plates during the staving up process. If holes are drilled in place in such position that they cannot be solidly bolted, the Bolter should follow after the Driller, and slack off such drilled plates, cleaning out all "chips" and "rags" that may have lodged between the faying surfaces. The "faying" surface is that surface of the plate which the punch enters. (On its exit it leaves a "burr.")

In bolting up a section about to be riveted a bolt should be placed in every second hole, for heavy work. If these bolts are well hove up, the joints will be solid and the riveter can do good work very rapidly. If bolts are placed too far apart, the rivet swells out between the two surfaces of the plates being riveted and a tight joint is not possible. Very close bolting is necessary, too, because the large amount of hammering which a long plate receives in riveting will lengthen it out and make a great many unfair holes if the bolts are not placed close enough to prevent movement.

While the Reamers are working in a "berth" a couple of Bolters follow along and place a bolt in each hole reamed, heaving it up solidly. The bolt first placed is now removed, and the Reamers go over the berth again, reaming all holes in which bolts were located. After the Reamers have completed a berth it is ready for the Riveters.

The Bolter must be careful in his work to see that the holes are true, and in line, when leaving work for the reamer.

He will find it impossible to make all holes stand perfectly true, but by the use of the drift pin he must get the greatest possible number into line, having no "half blind" holes.

(A "berth" is a space arbitrarily fixed by the foreman riveter between certain frames, fore and aft and from one side to the other.)

Duties of the Drillers and Reamers

The duty of the Driller and Reamer in shipbuilding is to drill, ream, and countersink various parts of the ship which must be machined after they are in place on the frame. Drilling consists of cutting holes in the various parts at selected positions by the use of small tools known as drills. These tools are operated by a pneumatic drilling machine.

Drills should be kept sharp; and it is well to have a stock of them in your tool box when going aboard the ship, and return them to be repaired when they become dull. In drilling use a small amount of cutting material, soap and water squirted on the drill with an oil can.

The Reamer is used for finishing out holes that may be unfair. It is placed in the machine the same way the drill is, but the work is not so heavy. Soap and water or oil should be used when reaming.

The speed of the machine is controlled by the amount of air that is admitted to it. In drilling the machine may be run fast enough so that the chips cut from the hole are blue. For large size drilling, that is holes over ½ in., two men work together, a Driller and a Helper. For work under ½ in. the Driller works alone. In reaming the machine is run a little slower than for drilling.

Countersinking consists of enlarging the face of the hole, to take a countersunk rivet point. The countersink is a large drill sharpened to the correct angle at the point. These tools are kept in the proper condition in the tool room. The cutting material used on drills,

reamers, and countersinks is soap and water or special oil, known as cutting oil. The following are helpful points on the care of the pneumatic drill:

Keep the parts clean and well oiled. The valves and pistons require a thin oil, and when operating constantly they should be oiled every hour. The gears should be greased with a heavy grease every ten hours when they are in constant use. Oil may be put in the air connection where the air pipe connects while grease is put in the hole in dead air handle.

A duty of the Driller is to tap for tap rivets. The tap rivet is screwed into place instead of being driven, therefore the hole must be smaller than the body of the rivet, in order to allow for the thread. The drill used for tap rivets is $\frac{1}{16}$ in. smaller than the body of the rivet for $\frac{1}{2}$ in. rivets and $\frac{3}{32}$ in. smaller for all other sizes. The method of drilling for a tap rivet is not different from any other drilling, excepting that the drill is smaller; that is all. Making the thread is done by means of a tap, which has a fluted body, threads cut on it, and is hardened and tempered so it will cut steel. Cutting oil or soap and water is used when cutting the thread. Tap rivets are used in places where it is possible to get at only one face of the work, to head up a driven rivet. Often the hole is "blind," that is, it does not pass completely through the part into which it is driven.

On certain classes of work located in corners and other limited places it is not possible to use the regular pneumatic drill. For such work the corner drill is used. (See "Shipyard" Tools.)

The Driller must be careful not to break the tap when tapping on this class of work. Drill the hole about $\frac{1}{2}$ in. deeper than required by length of the rivets; run the tap in $\frac{3}{8}$ in. deeper than required by length of rivet and you will avoid broken taps. Taps have twelve and fourteen threads per inch.

A Laborer assists the Driller in feeding the drill to the work. As a drill is breaking through the plate, the pressure should be lightened, otherwise the drill would catch and be broken; this catching is called "bighting." When countersinking, the pressure is put on the drill by pressing on the handles.

The angle of countersink is greater for thin plates than for thick ones. Reamers, taps, and drills are measured by their diameters.

In countersinking the Driller runs the countersink to within $\frac{1}{16}$ in. of the depth of the plate, thus the plate thickness forms a guide, telling him when the countersinking has been completed.

Holes much out of line must be reamed large.

Duties of the Riveter

The rivet, though small, is an important element in ship construction. The proper placing of the rivets in the various parts of the ship is an important work. It requires skill, and the workman should be rapid in doing his work, in order that the building of these ships may not be delayed.

All rivets used in modern shipbuilding are of steel.

The various kinds of rivets are as follows: Pan head, snap or button head, flush or countersunk head, countersunk raised head, and tap rivets. Points are snap, hammered and countersunk. Pan and button head rivets ½ in. in diameter or over have coned or swelled necks for punched plates, and straight necks for drilled plates. The advantage of swelled neck rivets is that the diameter of the punched hole on the die side of a plate is always slightly larger than on the punch side. In assembling, the plates are reversed, and thus with swelled neck rivets the holes are completely filled.

The proportions of the heads and countersinks vary with the different classification societies, There are no universal standards. Following are Lloyd's proportions: Countersink for plates in which countersink head and point is to be used should extend through the whole thickness of the plate when less than 14/20 or .7 in. thick; when .7 in. or above, the countersink to extend through nine-tenths the thickness of the plate.

The length for ordering pan and button head rivets is measured exclusive of the head; for countersunk rivets and taps the ordered length includes the head to the top of the countersink.

Rivets are placed in a ship by a number of gangs. Each gang consist of a Heater, a Holder-on, and the Riveter. In remote places on the ship there is introduced in this gang an extra boy to pass the rivets from the Heater to the Holder-on, who inserts it in the hole ready for driving. Many times the Heater Boy throws the hot rivet through the air to the Passer Boy, who

receives it in a "catching can" and then places the rivet in the hole. This boy is known as the Passer Boy. The duty of the Holder-on is to hold the rivet in the hole solidly in place by means of the holding-on tool. The duty of the Riveter is to drive or "stave" the rivet point up solidly against the plate so that the two parts of the plate are firmly jointed together. In shipbuilding practice this is done by means of an air hammer, which is the implement used by the Riveter in doing practically all of his work. It is operated by compressed air, fed to it by means of the hose which is attached. The riveting tool, or "die," as it is known, is placed in the socket of the hammer and held firmly against the point of the rivet, which is rapidly driven into place. The hammer is started and stopped by pressing the air valve lever, directly under the operator's hand, in the handle of the hammer. The driving end of the hammer is supported in the left hand of the operator, while he uses his right hand for controlling the air valve and pressing the hammer firmly against the rivet to be staved.

One of the particular points which must be gained by experience is the amount of driving necessary to firmly join two plates.

Heating the rivet properly is important. If the rivet has not been heated sufficiently, it cannot be driven solidly into place, while if it is too hot it is burnt, and therefore useless. When the Heater is working at the furnace, he keeps a large number of rivets in the heat at one time. He should place the points of the rivets down so that they are heated quite hot, while the heads are not heated as

hot. This is necessary in order that the point may be soft, while the head will be hard in order to hold in place during the staving process.

The rivets are handled by tongs which enable the workman to pick them quickly from the furnace, pass them to the required position and insert them in the holes punched in the plate. After the rivet has been properly heated, it is passed by the Heater to the Holder-on, who places it in the hole and immediately places against it the "holder-on." A tool known as a "dolly" is used on some work instead of the holder-on; the dolly is a hand tool, which serves the same purpose as the pneumatic holder-on.

A number of different sizes of hammers are available for different classes of work, as will be seen in going over the table on page 28. There are a few important features relative to the care of the hammer to which the operator should pay attention. Do not roughly use this tool, as some parts of it are very accurately made and the serviceability is greatly increased by its careful handling. Pneumatic hammers must be properly lubricated in order to give desirable results. One of the most important factors connected with their care is to keep them clean and well lubricated; when working constantly, you should disconnect the air hose once in three hours and squirt some oil into the air hose connection. If the hammer does not work properly, report it to the foreman in charge of the gang, and let him give directions as to what should be done in order to keep the tool in good condition. As the air taken into hammer contains some

particles of grit or dust, it is impossible to prevent this matter from entering into the working parts and thus doing damage.

The use of a poor grade or heavy oil will cause trouble in the operation of the hammer. A good plan to follow in cases where oil which is too heavy has been used for lubrication, is to clean the hammer thoroughly by the use of benzine or gasoline, which is put into the hammer through the hole in the end where the air tube connects. (The air tube connects on the lower part of the handle of the hammer.) This loosens all foreign matter and cuts the thick oil, which then can be removed by blowing the air through the hammer. It is an excellent plan to put the hammer in a bath of benzine over night occasionally, then blow out any dirt by connecting the air tube in place, thus cleaning the hammer thoroughly. Such treatment not only prolongs the life of the tool, but makes it much more efficient in use. The workman should keep in mind that the riveting hammer is made with all the parts proportioned to meet the various requirements of the work to which these tools are adapted. Occasionally a workman will attempt to make some changes in the parts of the tool, a practice that is decidedly objectionable. The parts of the tool should be used as furnished by the makers, and when parts are worn out they should be replaced with new ones supplied from the manufacturers of the tool. Follow this plan and long and efficient life is assured this class of equipment.

The most flagrant violation of the proper use of pneumatic hammers on the part of workmen is to introduce

short pistons in the working chamber. These are rapidly worn out and cause a great deal of trouble, not only for the yard, but for the workmen as well. The reason why workmen sometimes follow this practice is because, for a brief period, the hammer will do a greater amount of work. This period of extra service is very short, and the tool is often ruined, due to the improper use mentioned.

There are available automatic oilers which may be used to advantage on these hammers. These may be used on all classes of this equipment. The table on page 28 will give a good idea of the service, which may be expected from various sizes of pneumatic hammers.

This table will also be of assistance in deciding the class of work which various kinds of hammers will do.

In the use of pneumatic hammers, a tool is placed in the end for doing the actual driving of the rivet. These tools are known as sets, and they are of various sizes to accommodate the different rivets. Hammers are available in both the round and hexagon style. Generally for riveting practice the round style of hammer will be found serviceable. The hexagon style is more desirable for chipping practice.

Duties of the Holder-on (Sometimes Called "Bucker-up")

The duty of the holding-on man is to hold the rivet firmly in place while the Riveter himself staves up the point. For the purpose of holding the rivet in place, a holding-on tool is used. This is a pneumatic device

Style	Size	Diameter of Piston	Length of Stroke in Inches	Cu. Ft. of Free Air Per Minute	Work to which this Tool is Adapted	Length Tool in Inches	Size of Hose Connection
Long stroke riveting hammers	#90	$1\frac{1}{16}$	9	25	Driving rivets up to $1\frac{1}{4}''$ diam.	$23\frac{1}{2}''$	$\frac{3}{8}''$
" " " "	80	$1\frac{1}{16}$	8	25	" " " " $1\frac{1}{8}''$ "	$22\frac{1}{2}$	$\frac{3}{8}$
" " " "	60	$1\frac{1}{16}$	6	25	" " " " $\frac{7}{8}''$ "	$20\frac{1}{2}$	$\frac{3}{8}$
" " " "	00	$1\frac{1}{16}$	9	25	" " " " $1\frac{1}{8}''$ "	$23\frac{1}{2}$	$\frac{3}{8}$
" " " "	50	$1\frac{1}{16}$	5	25	" " " " $\frac{3}{4}''$ "	18	$\frac{3}{8}$
" " " "	40	$1\frac{1}{16}$	4	20	" " " " $\frac{3}{16}''$ "	17	$\frac{1}{4}$
Chipping and caulking hammers	#0	$1\frac{1}{16}$	5	20	Ex. h'vy chipping and caulking	$18\frac{1}{2}$	$\frac{3}{8}$
" " " "	1	$1\frac{1}{16}$	4	20	Heavy chipping and caulking . .	15	$\frac{1}{4}$
" " " "	2	$1\frac{1}{16}$	3	20	Medium chipping and caulking	13	$\frac{1}{4}$
" " " "	3	$1\frac{1}{16}$	$1\frac{3}{4}$	15	Light chipping and caulking . . .	12	$\frac{1}{4}$
" " " "	A	$1\frac{3}{16}$	3	20	Heavy chipping and caulking . .	15	$\frac{1}{4}$
" " " "	B	$1\frac{3}{16}$	2	15	Medium chipping and caulking	$12\frac{1}{2}$	$\frac{1}{4}$
" " " "	BB	$1\frac{1}{16}$	$1\frac{1}{2}$	12	Light chipping and caulking . . .	$11\frac{1}{2}$	$\frac{1}{4}$

similar to the pneumatic hammer. In shipbuilding practice, a number of occasions arise for driving out rivets which have been put in place. For this purpose a tool known as a " rivet buster " is used.

In much shipyard work the rivets are placed one directly in line with the other. This type of riveting is known as chain riveting. Occasionally, a zig-zag or staggered riveting is used.

Most of the joints used in shipbuilding work are **lap-joints**, where one plate is lapped over another, in order to complete the construction. In certain parts of the ship a lap joint occurs over another plate, and in this case a " liner " must be placed. Ordinarily the Erector or Bolter will see that these liners are in place, but a Riveter should not rivet up a joint until he is sure that it has been properly lined.

In addition to the lap joint, which is the most common in ship work, the butt joint is used. Back of the joint there is placed a butt strap which reinforces it and holds the joint firmly together.

Regardless of the kind of joint that may be used in shipbuilding, a number of different styles of riveting may be introduced. Thus, there may be a single, double, treble or quadruple riveted joint. A single riveted joint is a joint having one line of rivets; double, two lines, treble, three lines, and quadruple, four lines. Except in a few cases, in ship construction the following sizes of rivets are used: $\frac{5}{8}$ in., $\frac{3}{4}$ in., $\frac{7}{8}$ in., 1 in., and $1\frac{1}{8}$ in. Designers make an effort to limit the sizes of rivets to as few as possible. Rivet holes are always punched or

reamed larger than the rivet that is to be driven. The finished diameter of the rivet when staved up is larger than before it was riveted. In specifying the size of rivets, it is always the diameter before staving up which is given. The allowance made for the swelling of rivets is roughly taken from $\frac{1}{16}$ to $\frac{3}{32}$ of an inch. The latter dimension is the amount which a $\frac{7}{8}$-in. rivet will swell in staving up, and the former, the amount a $\frac{5}{8}$-in. rivet will swell.

In riveting watertight joints, the rivets are placed closer together than in joints where watertightness is not necessary. In a lap joint, rivets must be so close together that the distance between a pair of rivets may not give a section of plate, which is flexible enough to spring apart under the separating action of the caulking tool. Hence the reason for this necessity of very close rivet spacing on all parts of a ship that must be watertight.

The "grip" of a rivet is the distance between the head and point after it has been staved up. Thus, a rivet holding two plates together has a grip equal to the measure of the thickness of the two plates, plus a small amount as given later. The pitch of a rivet is the distance measured from center to center of rivets along the line of the riveting. That portion of the plate edges which lap and through which rivets are driven is spoken of as the "plate-landing." The end joints of the shell plating are overlapped. This type of joint is more efficiently caulked than the butt joint. The riveting of the shell landings on a ship binds the different strakes into one continuous surface.

Particular care must be observed to secure fair holes in three-ply riveting in the frame joints and gunwale bar.

If the holes are punched in the plates the rivets used in shipbuilding are slightly swelled in the neck, that is, that portion just under the head. This is necessary in order that the rivet may seat itself soldily in the punched hole when it is staved up. Holes punched in ship plating are slightly tapered, and a straight rivet is apt to leave an empty space within the riveted section. When a rivet is driven into a plate there is some danger of the head not being solidly set against the plate. To avoid this, therefore, the rivet should be well "laid up," that is, immediately after the hot rivet is placed in the rivet hole it is struck a few blows, either with a hammer or by operating the pneumatic holder-on to set the rivet well into the hole and the head against the face of the plate. The head of the rivet should not be struck after the final staving up, as this is apt to loosen it. As will be seen later, however, the point is finally finished after the rivet has been driven in place.

The pan head rivet is used extensively in shipbuilding construction. This rivet possesses the important quality of strength and has a solid clamping effect on the plate. It is very easy to hold up during the staving operation.

The snap head rivet is used but little on shell work. It is applied, however, on the floor frames, and other inside sections of the ship.

The countersunk head rivet is employed where a flush surface is required, as on the gunwale. It is also used in many places where watertightness is very important

because the making of a water-tight joint with a countersunk rivet is a comparatively simple operation.

The countersunk rivet, when finished, may or may not be perfectly flush or flat. When it is to be flush it must be chipped and finished off quite carefully. Where a perfectly flush surface is not necessary thé rivet is allowed to set beyond the plate a small fraction of an inch as permitted by the specifications of the ship being built. The countersunk rivet is especially suitable for three-ply riveting, such as occur in many places on a ship.

The snap point is not extensively used in ship work, but since there are occasions when the workman must finish such a point, the following notes relative to this type of point will be of value. The rivet should first be staved up by holding the hammer so that it strikes directly on the end of the work until the shank grips the hole solidly. In this particular part of the operation the hammer is given a slight rolling motion. The rivet just finished is left, and a second rivet staved up as mentioned. Following the staving up of the second rivet the workman returns to the first rivet and finishes by striking a few rapid blows after the work has cooled somewhat. This latter driving produces a nicely finished head.

In working up the riveting, holes are sometimes found which are not in line one with the other. Such holes are said to be "unfair," that is, they are out of line with each other. The riveter should never drive a rivet unless the holes are reasonably true. If they are unfair the bolters should be called and the plates drifted into proper position or "picked" out. The term "picked," as used in

this sentence, applies to the chipping off of the edge of a hole with a gouge, so that the rivet may enter in the proper position. Holes which are out a great deal must be reamed larger. This work is attended to by the drillers and reamers. If all holes in the ship are reamed, the difficulty of unfair holes is largely done away with.

A half blind hole is one in which the hole in the plate on the inside laps over the outside hole approximately half of its diameter. When a hole is out of line to this extent it should always be drilled and reamed before riveting. Whatever the nature of the plating surface before riveting, it is rendered fixed and solid by the riveting process; therefore, it is important that the surface shall be properly aligned before rivets are driven.

Rivets are heated in small movable hearths. Either coke, gas, or oil is used for making this fire, and a blast is obtained from the compressed air tank which produces a hot flame. In heating a rivet, some Rivet Heaters use a punched plate, laying it over the top of the hearth, into which the rivets are laid, during the heating process. Such a plan assures efficient heating and is very convenient, especially for beginners. After considerable practice such a plate is hardly necessary, however.

Proceedure in Riveting

Rivets are staved up as follows: the hot rivet is inserted in the hole and the pneumatic holder-on or the dolly placed against the head. After the rivet is placed in the hole the holder-on is operated in order to lay the

rivet up and give the head a good bed on the plate. It will be seen that the holder-on prevents the rivet from being driven out of the hole during the process of staving. At first the rivet is struck by the hammer fairly on the end, so that the shank may be staved up, and fit the hole throughout its length. If it is a countersunk point and the rivet shank is rather long, which is usually the case, it is then struck to one side, slightly, so as to bend it over in such a way that the extra material not required to fit the countersink may bulge to one side and thus be readily chipped off while it is hot. This piece of the rivet which is pushed to one side is known as the "rag." After thus staving up the rivet the Riveter lays the riveting hammer aside and takes his chipping hammer and chips off the rag. He then takes his riveting hammer and gives it a second series of blows, delivered with care, around the edge, so placing his hammer that the rivet raises slightly towards the point. This process thoroughly caulks the rivet and finishes it off smoothly. If the Riveter is skillful it will be difficult to tell exactly where the rivet is located in the plate because of the very smooth finish thus produced.

After the first series of blows has been made, the rivet point shows a slightly bluish color. If the second series of blows is given at the proper time, this bluish color will entirely disappear and leave the rivet the same color as the adjoining plate.

In working during hot weather when the rivet cools slowly, it is wise to delay giving the final series of blows until another rivet has been clinched.

In order to insure a perfectly tight joint it is a good

plan, when giving the final series of blows, if the plate also be given a few blows along the edge, between the rivets, so as to bring up the faying surface everywhere into close contact. In placing shell riveting, it is customary to assign a section or "berth," as it is termed, to each riveting squad. The usual procedure is to rivet each landing, one after the other, beginning with the garboard strake, being sure that this strake is properly faired up before starting riveting. The rivets are then hammered up one after the other, the frame rivets and butt joint rivets being taken in their order. The Riveter should be careful that he rivets up only those frame rivets located from center to center of each strake. That is, he should not rivet for a long distance up a frame, leaving a number of butt joints, to be riveted between the frames.

Occasionally a Riveter finds it necessary to work in a place where the pneumatic holder-on cannot be conveniently used. Under such circumstances a "dolly" is used to hold the rivet in place, the rivet being laid up with an ordinary hammer, or by striking it with the dolly.

In the stem and stern frames of the ship, very long rivets are used. Where this is the case, the rivet must fit the holes very closely and be driven in place. Such long rivets are heated only at the point and never in the body. The Heater, after the rivet has been brought to the required heat, sometimes cools the body of the rivet in water before driving it into the hole.

All rivet work must be tested in ship construction in order to be sure that the rivets are tight and sound. The

closeness of a joint may be tested by the means of a thin-bladed knife, the insertion of which between the faying surfaces should not be possible. In poor work the testing knife may be entered freely into the joint. This should not be possible at any portion of a riveted joint. A tight rivet can be tested by striking with a light hammer. If the rivet is not tight a jarring noise can be heard, and the hammer will not give a sharp rebound. A tight rivet when struck with a hammer always gives a sharp, clear, ringing sound.

In testing a rivet the workman places his finger against the head and plate, and hits the rivet a few light taps. The sound, together with the sense of touch, after a very limited experience, will enable the worker to tell at once whether or nor the rivet is tight.

A defective rivet may sometimes be made good by heading up slightly while it is cool. If a few blows do not produce a solid rivet, however, the rivet should be "backed" out and a new one put in its place.

Tap, stud, or screw rivets are used in riveting the shell plating to the stern frame. This is not a desirable form of rivet for a general run of work. Tap rivets are screwed in place by means of a wrench in a manner similar to that in which a bolt is tightened up. They should fit the hole in which they are placed tightly, so that there may be no chance for them to loosen in their seat. The holes for tap rivets are usually countersunk in place on the ship and the rivets are screwed tightly into place, after which they are staved up in a manner similar to that for the ordinary clinched rivet, in staving use the

hammer so as to tighten the rivet, striking to turn rivet to right.

For the purpose of screwing up a tap rivet a square protection is left on the head. Tap rivets are used in places where it is not possible to work from both sides of the joint in riveting. A great many of the long rivets used about the stern of the ship must be of this type.

When staving up a rivet the Riveter chips off the extra material left over after the staving up process. The rivet should never be hammered down and spread out over the outside surfaces of the plate.

Allowance for Points in Length of Rivets with Two Thicknesses Connected

	Diameter of Rivets					
Type of Point	½	⅝	¾	⅞	1	1⅛
Countersunk..........	½	⅝	¾	⅞	1	1⅛
Hammered............	½	½	½	⅝	⅝	⅝
Snap..................	⅞	1	1⅛	1¼	1⅜	1½
Oval..................	⅞	⅞	...	...	...	...

The above allowances are based upon the average practice at various United States Navy and private shipyards.

Rivets are shipped in kegs of 100 and 200 lb. In ordering the diameter should be given first and the length following, thus: ½ in. by 3 in.

A few words concerning the use of certain riveting tools, which are somewhat special, will be of assistance to beginners in shipbuilding.

The holder on requires a considerable space in which to work; for this reason short holder-on tools are used. In other classes of work it is not possible to use a holder-on

with a piston located centrally, under such circumstances an offset holder-on may be used. These tools may be conveniently used in any place where there is not sufficient room to use the regular holder-on. When it is necessary to work in a very limited space, use the short holder-on; either the central or offset type may be applied, depending on the position in which it is necessary to work.

There are certain rivets in a ship so located that it is impossible for the workman to hold the riveting hammer in such a way as to work effectively. For this class of work the "jam riveter" is used, bracing it against the frame, while it is working.

In certain places in a ship the holder-on must arrange rigging to support the holding-on tool while at work.

In riveting the workman must be sure that he selects a rivet long enough to form the point he wants to make. If the rivet is not long enough the point cannot be formed. If it is too long, stock is wasted. The table just given will enable one to quickly determine the length of rivet to form a point. The plain rivet is the snap form. For special rivets, instructions should come from the design department, giving amount of stock to be allowed for heads.

Length of "grip" is found by adding thicknesses of pieces to be riveted plus $\frac{1}{32}$ in. for each joint between plates.

Snap rivets should have points true to hole in which they are driven. Variation from truth can be detected by measuring the pitch.

The Inspectors should not permit much redriving of

cold rivets to tighten, nor allow excessive caulking of the rivet.

Pits, rough surfaces and cracks in a rivet indicate overheating, though these are not absolute proof of overheat. The inspector, when finding this condition should order a few of the bad looking rivets cut out; if the rivets do not yield readily to the "buster," if the break shown by cutting of the rivet head is clean and shows a good surface, the evidence of burning is misleading.

The detection of loose rivets has been described. Loose rivets are made to appear tight by going around the edges with a caulking tool. The inspector should look for caulking tool marks, and be guided by instructions from the office as to the amount of caulking he is to pass. Loose rivets on snap work are made to appear tight by side driving with the snap. Such driving leaves a ridge around the head, and when such ridges are found, the workman should be watched. These may not be loose in all cases, but observation of the workman will show whether it is tightening of loose rivets, or finishing the head that causes the suspicious marks. A few rivets may be cut out if necessary, in order that the inspector may determine the quality of the work.

Rivets should be watched on the "held up" side. A rivet may show perfectly tight on the point, but be loose on the head. Any marks on the head, or held up side of a rivet, indicate an effort to remedy some defect.

Countersunk rivets often give trouble, because the blank may be slightly long, and the excess material is allowed to spread out under the set, and overlaps the

hole. This edge if not quickly chipped off, will give the appearance of a tight point, when really it is loose.

In marking rivets to be cut out, use a center punch, making a deep mark. Paint the rivet, and put a mark on the plate beside the rivet, so it can be quickly located for a second inspection.

In selecting dies to do different classes of work the Riveter should remember that the same die is not used for all sizes of rivets, he should ask for a die that will fit the rivet to be driven, both for the holder-on and for the hammer. Dies are of various shapes. Those for snap points being different from those used for hammered points.

Rivets less than $\frac{3}{8}$ in. are driven cold.

Notes on Riveting

This is one of the most important parts of shipbuilding. At the present time a small vessel has been launched in Great Britain for which it is claimed that all the seams and butts are electric welded instead of riveted. It is not safe to condemn any new thing but at the time this is written riveting still is the only method in general use for connecting ship plates.

Details of the ship construction stand or fall according to the design in the drafting room and the care with which the work is done on the ship.

Two of the principal things are rivet spacing and type of rivet used.

Spacing of rivets is given in terms of the diameter of the rivet, as it bears a ratio or percentage of the whole joint.

The closest spacing is three diameters and the largest is eight diameters. All the different conditions in the ship are met between those two limits.

Oil-tight work requires the rivets nearest together as oil will seep through wherever possible and must be well caulked to prevent it, hence close spacing of rivets to hold the plates together.

Water-tight work calls for the next step up in spacing, being about $4\frac{1}{2}$ in. diameters. (This means $4\frac{1}{2}$ in. for a 1-in. rivet.)

Tank top, etc., come next with about 5 diameters.

Foundations require about 6 diameters.

Floor brackets, intercostals, etc., require about 7 diameters.

Beams to deck plating and non-water tight frames to shell plating take 8 diameters.

Plates are often punched the full size of the rivet. After the plates are together and regulated they are reamed out to full size of the rivet. Sometimes the holes are punched small and then reamed to suit rivet.

Rivets below $\frac{3}{8}$ in. diameter are driven without heating but all above that size must first be heated before they are driven.

In Lloyds Bureau of Shipping the standard thickness of a 1-in. plate is 20/20. Therefore a $\frac{1}{2}$-in. plate is 10/20, $\frac{1}{4}$-in. plate is 5/20.

The United States naval practice takes a plate 1 in. thick and 1 ft. square as being 40 lbs. in weight. A $\frac{1}{2}$-in. plate is 20 lbs., a $\frac{1}{4}$-in. plate is 10 lbs., etc.

As much of the work done in the United States is

according to the American practice it is well to become accustomed to the method of measuring by weight.

The following table may be taken as a useful standard:

$\frac{1}{4}$	in. rivet requires up to		$2\frac{1}{2}$	lb. plate also an angle with	1	in. flange.
$\frac{3}{8}$	" " "	3	" $5\frac{1}{2}$	" " " " " "	$1\frac{1}{2}$	" "
$\frac{1}{2}$	" " "	6	" $7\frac{1}{2}$	" " " " " "	2	" "
$\frac{5}{8}$	" " "	8	" $12\frac{1}{2}$	" " " " " "	$2\frac{1}{2}$	" "
$\frac{3}{4}$	" " "	13	" $19\frac{1}{2}$	" " " " " "	3	" "
$\frac{7}{8}$	" " "	20	" $29\frac{1}{2}$	" " " " " "	$3\frac{1}{2}$	" "
1	" " "	30	" $39\frac{1}{2}$	" " " " " "	4	" "
$1\frac{1}{8}$	" " "	40	" $50\frac{1}{2}$	" " " " " "	$4\frac{1}{2}$	" "

This table should be fixed in the memory as it forms a basis for estimating required sizes. Having given the thickness of plate one can know at once just what size rivet is required and what size of an angle. (As a general thing the thickness of the angle is about the thickness of the plate in order to be of service.)

When two plates are joined the size of rivet called for varies if they are of different thickness, according to the work to be performed. If it is for a strength joint, then use a rivet for the thicker plate; if it is for an oil- or water-tight joint then use the rivet as required for the thinner plate.

Riveting is generally more than single riveted when connecting two plates.

Fig. 1 shows double, chain riveting. If there were a third row it would be treble, chain riveting, etc.

Fig. 2 shows "staggered" or "zigzag" riveting. This is often used when an angle with a broad flange is connected to a plate.

Fig. 3 is an angle with unequal legs. When one leg or flange of an angle is against a plate the other is called the "standing" flange. When an angle of unequal legs is shown on a blue print, the flange which is shown laying

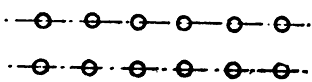


FIG. 1.

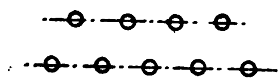


FIG. 2.

flat on the plan is read first, i.e., 3½ in. by 4 in., or 4 in. by 3½ in. according to which is facing you.

All angles are formed at 90 degrees and when necessary for ship work they are heated and then "beveled."

Fig. 4 shows an angle at 90 degrees, dot and dash line is an "outside" bevel, the dotted line is an "inside"

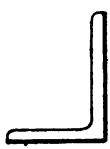


FIG. 3.

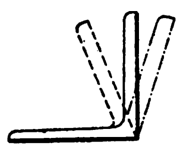


FIG. 4.

bevel. Inside bevels are to be avoided as they are very difficult to rivet.

The outside point of the angle is called the "heel" and all measurements are taken from the heel. The two ends are called the "toe" of the angle. The inside, opposite the heel, is called the "bosom" of the angle.

Fig. 5 is a channel bar. The long part is called the " web " and the two smaller parts are called the " flange." The channel also has a heel, toe, and bosom.

Angles and channel bars are the two most common shapes now used in merchant shipbuilding. There are other " shapes " (a distinguishing definition from " plates ") used in naval work but they will not be mentioned here.

Rivets are made up of a " body," a " point " and a " head." The body is in the form of a bolt and the diameter of the body determines the size of the rivet. The head and point of the rivet vary according to the kind of plating which is to be connected by the rivet.

FIG. 5.

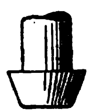


FIG. 6.

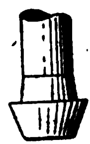


FIG. 7.

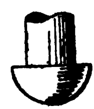


FIG. 8.

Fig. 6 is a Pan head rivet used for rivets below $\frac{1}{2}$ in. diameter or for a larger rivet in a drilled hole.

Fig. 7 is a " coned " Pan head rivet. This is used in all other places where a Pan head rivet is required.

Fig. 8 is a Button head rivet. This is used for casings and some foundations where flush work is not required.

Fig. 9 is a " coned " Button head rivet.

Fig. 10 is a Countersunk head and is used where the surface must be smoothly finished.

Fig. 11 is a "raised" countersunk head and is used where the work is to be flush but the head must be caulked.

Fig. 12 is a "Tap" rivet. This is a threaded bolt with a countersunk head. Above the head a square end is left to turn the tap into the hole. After it is in place the

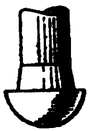


Fig. 9.

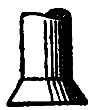


Fig. 10.

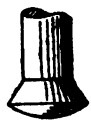


Fig. 11.

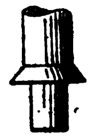


Fig. 12.

end above the head is chipped off. These are used where plates or shapes are fastened to a casting.

Fig. 13 is a Countersunk point rivet used for flush work. When driving shell or deck rivets the finish is not exactly flush but the point of the rivet is drawn up a little

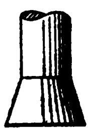


Fig. 13.

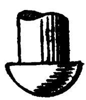


Fig. 14.

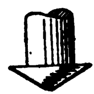


Fig. 15.

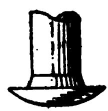


Fig. 16.

in the center so it will project a trifle beyond the plate, to be sure there is ample material.

Fig. 14 is a Snap point rivet and is generally used for a Button head rivet.

Fig. 15 is a Hammered point rivet. This type is used as specially required.

Fig. 16 is a Liverpool or Oval point rivet. This is used on a finished, exposed surface with thin plating.

Duties of the Caulkers' and Chippers'

Caulking

The Chipper trues up all irregular plates, cuts off plate edges that are too long, chips bosom pieces and similar work.

The Caulker tightens up all work that must be water-tight. This work is done on shell plate edges and butts, water-tight floors and bulkheads, and around the decks as the caulker may be directed by the man in charge of his work.

For chipping and caulking a hammer of the same design as the riveting hammer is used. The tools have a hexagonal shank which fits in the hammer. Two kinds of chisels are used, the "cape" and "broad" chisel. The broad chisel is used on open work, the cape for getting in corners and close places. For most ship work the chisels are "side ground."

The following tools are used for caulking:

The flush "splitting" tool, the flush "making" tool and the "reeding" tool. The final step in caulking is the reeding or finishing. Flush caulking is also spoken of as butt caulking.

The lap caulking tools are the splitting and the making tools to be described later.

By caulking is meant the forcing of one surface of metal hard against another, producing a water-tight joint. In "staving up" the edge of one plate it forces it into contact with the surface of another. Caulking may injure a joint if improperly done; therefore, a caulker should

be careful not to spread out the edge of the plate. In caulking, a "splitting tool" is first used so as to make a narrow furrow along the edge of the plate about $\frac{1}{16}$ in. deep. Then a setting tool is used which completes the caulk by squaring out the groove. The setting tool is practically the splitting tool reversed. This square groove forming the "caulk" is from $\frac{1}{8}$ to $\frac{3}{16}$ in. wide and $\frac{1}{16}$ in. deep. The first width is used on thin plates, and the latter on the heavy plating. If very nice work is wanted, a third tool known as a "finisher" is used. It is a regular caulking tool, and is applied lightly along the caulk. In caulking, the shoulder should be deep and square. To produce this deep shoulder a heavy caulking hammer must be used.

In caulking a butt joint the edge of the plate is thinned out and the parts jammed together. Butt joint plates must be carefully fitted close together in order to produce a tightly caulked joint. The watertightness of a butt joint depends on the caulking, therefore, it must be carefully done.

In caulking a butt joint the caulker must watch the line of the seam closely, so as to follow it. The caulking tool should not be allowed to slip first on one side, then on the other on the joint, because this will produce poor and bad looking work.

The hammer for caulking work is one in size between the heavy riveting hammer and a light chipping hammer. (See table on page 28, of hammer sizes for the tool to be used.) For caulking on test work use the B.B. $1\frac{1}{4}$ in. stroke hammer.

A number of seams on a vessel are so placed that they must be caulked with the handle of the tool held in the left hand. The lap joints on the strakes of the starboard side of the ship are "left-hand" work. Skill in this requires practice.

Designers so place the parts inside of the ship that left-hand caulking is avoided, that is, the horizontal caulking edges face upward, and bulkheads caulked on forward surfaces have vertical edges facing to port, and those caulked on after surfaces have vertical edges facing to starboard.

The perfection of caulking work is tested by inspection of the groove formed by the tool. This groove should be of proper width and be deep, not just a slight mark. The edge of a knife is run along the seam; if it can be inserted at any point the caulking is poor, and must be done over. When inspecting in dark places, as at the bottom of the ship, use a light so that the seam can be properly examined.

The groove on shell plating should be $\frac{3}{16}$ in. wide. A narrow groove indicates a high shoulder. The depth of the groove is left to the judgment of the caulker. If plates are close together when caulking is started, the groove need not be deep. If they show open, as is often the case at the bilge, the groove must be deep to produce a tight seam.

When caulking, don't hold the tool so it cuts into the adjoining plate.

The toes of an angle are rounded, and in order to caulk properly they must be planed, sheared or chipped before caulking, if the best work is wanted.

Caulking a straight seam is not a difficult job. In caulking collars and lugs, however, considerable practice is necessary before a caulker is capable. To close open spaces the caulker drives chips, or wedges of steel, into these open places, and the surface of the collar caulked over a large area. Instead of the regular caulking tool, a tool known to the caulker as a "butt tool," is used, which is made by heating red-hot the blank from which the tool is made, and driving the end on a coarse file. In caulking large surfaces, the smooth caulking tool will slide about in such a way that nothing is accomplished. The butt tool holds steadily to its work. This tool is used for caulking butt joints, but it should not be used for seam joints because it tears the plate.

In caulking oil-tight work, all lugs and angle bars are caulked all around it. In beveled angles the heels may be $\frac{1}{8}$ in. away from the plate at places. It is necessary under such conditions to force soft packing into the opening, and then use the splitting and caulking tool.

In caulking a water-tight bulkhead, it should be done entirely from one side. If it is done partly on one side and partly on the other, water-tightness would not be secured.

In good caulking there is no stopping point where water may pass, the caulking lines forming a continuation all over the ship. If double frame angles are used at the bulkheads, only one is caulked; this is the after frame angle on forward bulkheads, and forward one on after bulkheads. The bulkhead should be caulked on the same side that the frame angle is caulked. Around the after

peak and deep tank bulkheads, where soft packing or putty is placed at the frames, the caulker should be just as particular with his work as where packing is not used.

Where the overlapping deck plates are linered, these must be caulked. Where continuous parts, such as stringers and frames, pierce water-tight bulkheads and tank tops, they are surrounded by "collars" of different forms. These collars often come to the ship already formed, are located by the erectors, and riveted up. They must fit closely around the part, and all should be on the same side of the bulkhead that is caulked.

The side of a bulkhead that is caulked should be open for inspection; that is, a tank should be caulked on the outside, whenever possible, because leaks during testing are much more easily located. Particular care should be observed in caulking, that the tanks in the double bottom are caulked on the open side. The oil storage tanks are caulked on both sides.

In testing a tank, if a leak is found that cannot be corrected by caulking, rivets must be driven out and renewed. To do this, the tank must be emptied and a second test made after the tank is filled again.

The shaft tunnel is caulked, and specifications may require testing this with water, the hose test being used. The decks are tested with the hose test. This test is described later. The ballast tanks of new vessels need very careful caulking.

CHIPPING

Some of the sight edges as left by the bolters and riveters are not fair on bottom, on bilges, at sides, and on the decks. These unsightly places are corrected by chipping, before any caulking is done in the berth on which the caulker is working. Be careful not to cut into the adjoining plate when chipping a sight edge. For this chipping use a hexagonal shank chisel and the proper hammer for it.

The chisel used should be sharp and ground at the proper angle. Chisels are furnished already ground, and if not properly ground should not be used.

All chisels and caulking tools are furnished the worker hardened and tempered. If the edge of the chisel does not cut when it is placed on the work, it is soft; the edge will be seen to turn back. Lay this tool aside and get another. Have a good stock of tools when starting on the job.

STOP WATERS

Riveted joints may be made tight without caulking by placing tarry material between the fitting surfaces. This material may be made of strips of flannel or lamp wick dipped in red lead. Felt sheeting is also used for this purpose. At some places a kind of putty known as Vulcan Cement is used. This is mixed with linseed oil, to give it the consistency of a stiff dough, and worked into the joints with a case knife or small trowel. "Rubberoid" is used as soft packing. It is placed between

the fitting surfaces when erecting and the heat of the rivets when riveting makes it soft and sticky, thus assuring watertightness. This soft packing is used on all joints that cannot be properly caulked, also in such joints as may be very difficult to caulk, due to the complicated construction of the hull. It is used on all water-tight collar angles, tank divisions at the bottom, margin plate lugs, bars on top of tank, etc. Soft packing is not as desirable as metal caulking, but there are places in the ship where it must be used.

Soft packing known as "stop waters" is used at shell landings where they are crossed by a water-tight bulkhead. The erector must see that these are in place when the shell is erected. Even with great care leaks occur between surfaces, which in final testing cannot be located exactly, and then a putty stop water is put in by means of the pump. To use this pump a hole is drilled and tapped in one surface where the leak shows, and the nose of the pump screwed tightly into this hole. The plunger of the pump is screwed down and the whole surface is filled with putty. The putty used is made of red lead and boiled linseed oil mixed to the thickness of a very soft putty. After pumping in the stop water, a plug is put in the hole that was used to insert the pump. This is a $\frac{1}{4}$-in. pipe tap hole and will be drilled and tapped by the drillers.

When an inner and outer flat keel are to be made water-tight or oil-tight, two lines of "marlin" cord are carried along the length of the two keels, one just outboard of the line of rivet holes in the starboard side of the keelson

angles, and the other being just inside of the same row of holes.

Flat lamp wick soaked in linseed oil or some solution is placed between inner keel and bottom of keelson angles.

Duties of the Shipfitter

In this department there are divisions of Regulators, Linermen, and Shipfitters.

The Regulators are men who follow directly behind the Erectors and move the plating a fraction of an inch one way or another in order to take up any discrepancies in one plate by allowing a little shifting in a number of plates.

The Regulators use drift pins and heavy mauls in their work and after the plate is in position they bolt it in place, ready for the gang of Bolters-up who will thoroughly bolt it tight for the Riveters. When the rivet hole does not come fair, it is customary to use a smaller size bolt than the size of the hole. In this way a $\frac{3}{4}$-in. bolt would be used in a $\frac{7}{8}$-in. rivet hole which was slightly unfair. The regulating of a ship requires practice and the work of the Reamers is considerably less if the regulating men have done their work thoroughly.

The Linermen are men who follow up the Erectors, if the system of "in and out" plating is being used. This is a system where every other strake of plating is "raised" and requires a distance piece between the inside of the place and the framing. These liners or distance pieces vary in size and thickness, according to

the location. They are usually divided into "parallel" and "tapered" liners. The parallel liners are about the width of the flange of the angle which they touch and their thickness is governed according to the thickness of the inner strake with which they are in line.

The liners are punched for rivet holes, according to the spacing of the holes in the plates. The tapered liners are fitted under seams where a butt lap is used and are made to fill the triangular space which is left open.

The width of the liner is governed by the width of the seam (the lap on the edge of the plate) and is generally long enough to take at least two rivets, which are sufficient to hold it in place. These liners are usually delivered to the ship with a symbol painted on them, indicating their location and it is the duty of the Linermen to distribute these according to the marking and see that they are in place ahead of the Bolting-up gang, so that when the Riveters are ready for their work there will be no delay.

The Shipfitters are men thoroughly experienced in the shipbuilding work as regards the assembling of the ship structure. They must know every detail of construction about the ship and when any part of the ship comes in a little out of size, either too full or too scant, they must know how to make an alteration so that it can be properly adjusted. It is from this work that the name is derived, "Shipfitting."

It is also the duty of the Shipfitters to lay out watertight staples around angle bars, fit intercostal shell angles to the decks, fit and install watertight doors, hatch covers,

mooring rings, hawse pipes, rail and awning stanchions and all the other articles about the deck, which go to make up the deck fittings.

The Shipfitters are on such work from the time it is started and are in charge of the assembling of the ship itself. The supervision and carrying out of detailed construction on the hull goes on until the vessel is launched and after that time until the ship is ready for delivery they are busy with the many small fittings required both inside and outside on the decks. The shipfitter, in addition to his special knowledge of shipwork, must be a good mechanic and accustomed to using his head as well as his hands.

Duties of the Ship Carpenters

The Ship Carpenter does all the rough woodwork about a ship, including the building and truing of shipways, setting of shores, placing the staging and setting up backing for Riveters.

After the hull is well started, the work is divided up between a gang on the outside of the ship and another gang on the inside. This is necessary, as the need for staging must come under the eye of the foreman and where work is progressing rapidly he must be able to see where he can prepare in advance of the steel workers.

Staging work and backing does not require a great deal of skill, but men must be handy with woodworking tools. Some staging work is nothing more than planking on a couple of horses. On other occasions, it may demand

bolting uprights to various portions of the ships and putting in thwarts on which to lay stage planking.

The Shipways are prepared by an outside contractor. So far as piling of the foundations, building the cross-bents and decking, the ship carpenter's work starts with the keel blocking. The engineers give the inclination for the top of the keel block; they are then beveled, according to the line struck. The engineers then give the center line on top of the cap blocks. This line is carried down on the forward and after side of the block as well as across the top, so that when laying the flat keel it is possible to see the center line on the keel, in line with the center line on the blocks.

On the outside staging around the ship there is considerable work for the men, although the staging may have been placed along the side of the Shipway for a previous vessel.

As the ship progresses, work under the counter, around the stern requires special staging in the way of uprights and planks to enable the men to get in under the hull for the work on the shell. As this part of the outside staging is removed every time a ship is launched, this work must be done for each vessel.

The inside staging, generally necessary, is for riveting work around the inside of hatch coamings and under the lowest deck in the cargo holes, where the Holder-on must have facility for his work and easy access to it.

Inside staging between decks is usually done by means of horses with planks on them.

Many times it is necessary to shore up the inboard

end of half-beams when it is desirable to install these beams before all the material has arrived.

The ship carpenters must provide wood ladders for access to different parts of the ship and wide ladders, reaching from the bottom of each Cargo Hold to the Upper Deck with sufficient width so that two or three men may pass at one time.

The ship carpenters are on the lookout at all times to forestall the needs of the steel workers in the matter of additional staging, removing old staging, or altering it.

In the case where two timbers come together, it is better to bolt than to spike them, because the timber is in better conditions for use at some future time.

There are always plenty of bolts and angles about the Shipyard which may be used for connecting staging timber.

Many times a "jam riveter" must be used and the ship carpenters will be called upon to arrange the backing in heavy planks at proper distance from the plate to accommodate this tool.

As the boat increases in weight, it is customary in some yards to build cribbing under the bottom of the ship near the bilge, there being about three or four cribs on each side of the center line. This cribbing is a stronger support and more reliable than the ordinary shoring.

CHAPTER III

Shipyard Tools

Following is a list of tools used by **Bolters, Erectors, Shipfitters, Linermen, Regulators:**

$\frac{3}{4}$-in. and $\frac{7}{8}$-in. Spud wrenches with offset,
$\frac{5}{8}$-in. wrenches with offset,
Spud bars,
1-in. pipe handle,
Testing knives,
Center punches,
2-lb. and 8-lb. Mauls,
$\frac{3}{4}$-in. and $\frac{7}{8}$-in. Drift pins,
Soapstone,
Chalk,
Yellow crayons,
Turnbuckles,
Steamboat ratchet,
Heel wedges,
Straight wedges,
" C " clamps.

Reamers and **Drillers** use these tools:

No. 2 and No. 3 Air drill machines,
No. 9 Corner drill machines,
Ratchets,
2-in., 4-in. and 12-in. Extension sockets, 3–3,
Sleeve sockets, 3–4,
4-in. Sockets, 4–4, 2–4, 2–3, 1–3,
$1\frac{5}{8}$-in. and $1\frac{7}{8}$-in. Countersinks,
$\frac{15}{16}$-in., $\frac{13}{16}$-in. and $\frac{11}{16}$-in. Reamers,
$\frac{15}{16}$-in., $\frac{7}{8}$-in., $\frac{3}{4}$-in. and $\frac{27}{32}$-in. Drills,
Taps,
Grease guns,
Oil cans, 1 pt.,

Drift pins, Nos. 1, 2, 3,
Old men,
Eye-safe goggles,
Air hose,
1-in, Pipe handles,
" C " clamps.

The following tools are used by **Riveters, Holders-on, Heaters** and **Passers:**

No. 60 Guns,
No. 2 Chippers,
Holder-on machines,
Jam riveter,
$\frac{3}{4}$-in. and $\frac{7}{8}$-in. Snaps,
Concave dies, $1\frac{7}{16}$ in.,
Flush dies, $1\frac{3}{8}$ in.,
$\frac{7}{8}$-in. and $\frac{3}{4}$-in. Holder-on dies,
Heating tongs,
Passing tongs,
Catching cans,
" Y " Leader hose,
Hot chisels,
Eye-safe goggles,
Pint copperized oil cans,
Backing out punches,
Hand riveting hammers,
12-lb. Mauls,
Electric extension lights,
1-in. Pipe handles,
Gooseneck dolly bars,
Straight dolly bars,
No. 0 Dies,
No. 0 Countersunk dies and socket,
Rivet forge,
Testing knives,
Rivet testing hammer,
Red lead gun,

These tools are used by **Chippers** and **Caulkers:**

No. 1 and No. 2 Chipping guns,
Bobbing chisels,
Cape chisels,
Side cutters,
Gougers,
Roughing — straight, bent, fine,
Rivet caulkers—bent,
Rivet caulkers (Frenchman),
Fullers—straight and bent,

Caulkers—round, straight, bent,
Rippers,
Caulkers' dies,
Oil cans,
Eye-safe goggles,
Hand chipping tools,
Cold chisels,
Caulking chisel, straight, bent, round, fine, coarse,
Roughing chisels, straight—bent,
Diamond points,
Straight rivet caulkers,
Cape chisels,
Fullers—straight, bent.

Spud Wrench (Fig. 17): This tool is used by erectors or plate hangers when putting the plates together. The pointed end is used to direct the plate so that one rivet hole runs center over the one below it and the other end of the wrench is used for setting up bolts and nuts on the plates.

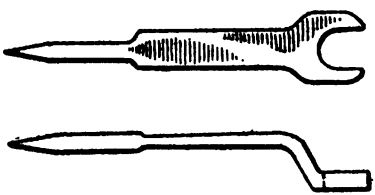


Fig. 17.—Spud Wrench.

Spud Bars (Fig. 18): These vary in length from 18 to 36 in. and are used in handling the plates when regulating them into the exact location required. One end is round and the other end tapers to a chisel point.

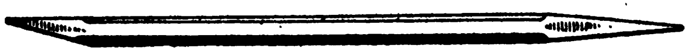


Fig. 18.—Spud Bar.

Rivet Testing Knives (Fig. 19): This knife is used by the rivet testers when examining the work to be sure that the joints between the plates are tight, without opening between them.

Fig. 19.—Rivet Testing Knife.

Figs. 20 and 21. These are the rivet testing knives which have been ground down to a shape as desired by

FIG. 20.

FIG. 21.

Rivet Testing Knives.

the workers. They are shown to give an idea of the different types which the men prefer.

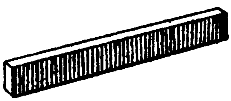


FIG. 22.—Soap Stone Marker.

Soap Stone Marker (Fig. 22): These are used as pencils by the steel worker as they give a clear line on the metal and can be sharpened down to a fine edge if required.

Mauls (Fig. 23): These are used for any heavy hammering about the ship, as by the regulating and bolting-up gangs.

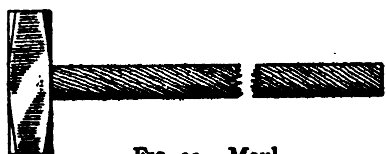


FIG. 23.—Maul.

Mauls (Fig. 24): This maul is used for backing-up when riveting and is used in place of the ordinary air tool for holding-on or in the place of a dolly bar.

FIG. 24.—Maul.

Drift Pin (Fig. 25): This is used for centering the plates when regulating them into the exact location required. When a plate is laid and the rivet holes are not exactly in line or "fair," the drift pin is hammered in, and, being in this tapered shape "round," it draws the two plates in line so that the centers of the rivet holes come one over the other, thus forming a "fair" hole down between the two plates.

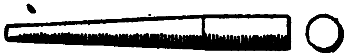


Fig. 25.—Drift Pin.

Turnbuckle (Fig. 26): This is often used when drawing plates into position.

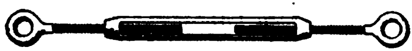


Fig. 26.—Turnbuckle.

Steamboat Ratchet (Fig. 27): This is used for work somewhat similar to the turnbuckle, but because of the hooks on the end it is often preferred. By swinging the ratchet handle the casting revolves, the right- and left-hand threads inside draw the two end links together (both ends are alike).

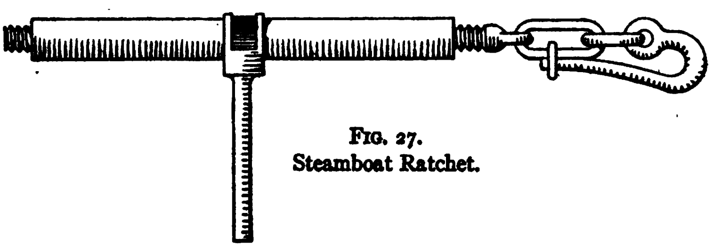


Fig. 27.
Steamboat Ratchet.

Straight Wedge (Fig. 28): This is used when regulating plates or when it is desired to raise the edge of a plate when fitting in liners or for some other reason.

FIG. 28.—Straight Wedge.

Heel Wedges (Fig. 29): These wedges are used in the same kind of work as the straight wedge and have th advantage of the heel on top, which is used for hammering against and backing-out the wedge.

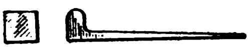


FIG. 29.—Heel Wedge.

Air Drilling Machine (Fig. 30): This machine is used for drilling and reaming. It is operated by means of two handles, air hose being attached to the valve which

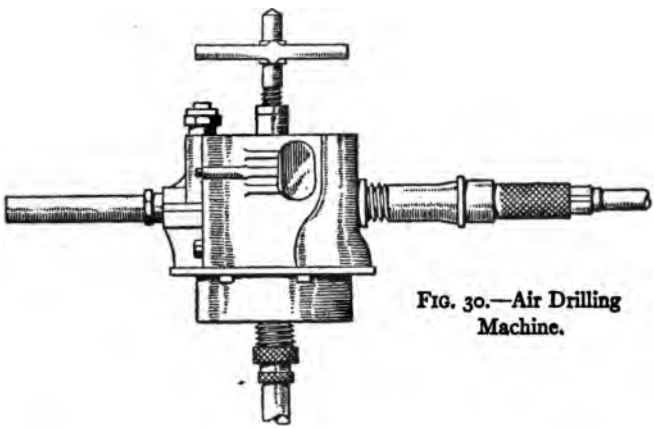


FIG. 30.—Air Drilling Machine.

is on one of the handles. The screw extension at the top is adjustable to hold the machine up to the work and is extended as the drill enters the hole which it is boring.

Corner Drilling Machine (Fig. 31): This machine is used in corners or any other location where there is small

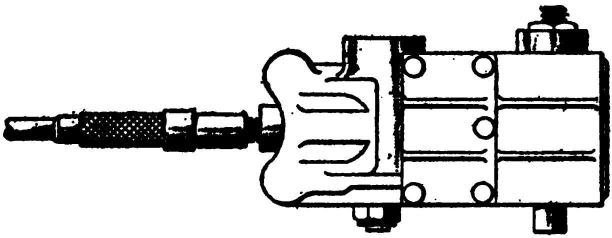


Fig. 31.—Corner Drilling Machine.

space. The screw at the top is set up with a lever which turns through a short arc. The valve is used as a handle on the back of the machine.

Wrench (Fig. 32): This is used for setting up the screw in the top of the Corner Drilling Machine, to raise the screw as the drill advances into the material.

Fig. 32.—Wrench.

Steel Socket (Fig. 33): This is used in the Corner Drilling Machine and takes the drill.

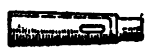


Fig. 33.—Steel Socket.

Hand Ratchet (Fig. 34): This is the old fashioned ratchet which has been used for drilling holes for many years. It is used in conjunction with the "old man" (Fig. 43), one hand moving the handle and the other tightening the back screw to maintain the pressure on the drill.

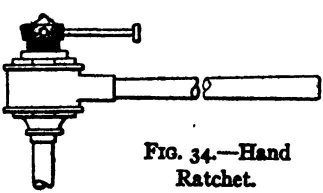


Fig. 34.—Hand Ratchet.

Countersink Drill (Fig. 35): This is used for countersinking any of the rivet holes as required.

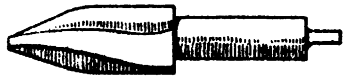


Fig. 35.—Countersink Drill.

Reamers (Fig. 36): The reaming tool is used in the air drill and comes in various sizes to suit the different size rivet holes. It makes the hole uniform, so that the rivet will be able to slide through easily before it is riveted up.

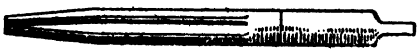


Fig. 36.—Reamer.

Drills (Fig. 37): These are ordinary machine tool drills used in the air drilling machine and are used the same as for any work where a straight hole is required.

Fig. 37.—Drill.

Taps (Fig. 38): These are screw thread cutting tools which are turned down into a hole after it has been drilled, in order to cut a thread for a stud or bolt.

Fig. 38.—Taps.

Tap Wrench (Fig. 39): This wrench is used for turning the tap when threading a drilled hole.

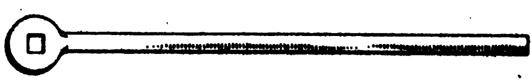
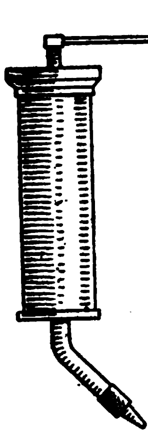
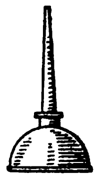


Fig. 39.—Tap Wrench.

Grease Gun (Fig. 40): This is a squirt can, or gun, used to lubricate the different air machines when they



are not in use. By means of the plunger, grease is forced out of the gun and drops onto the bearings of the machine.



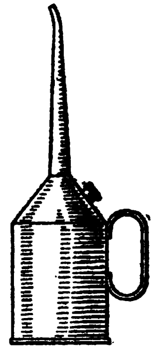


FIG. 40.—Grease Gun. FIG. 41.—Oil Can. FIG. 42.—Oil Can.

Oil Cans (Fig. 41): These are used for "oil" or "soup" (soap and water) for use of the Drillers in lubricating the work when drilling. Fig. 42 is another type of can used for the same purpose as Fig. 41.

"Old Man" (Fig. 43): This is a rig with a standpipe and base in one piece, a portable arm which can be raised and lowered or swung, to any angle, as desired. It is used when drilling, the base being on the material and the arm swung around until it is over the drill for which it forms a support and takes the thrust when the drill enters the material.

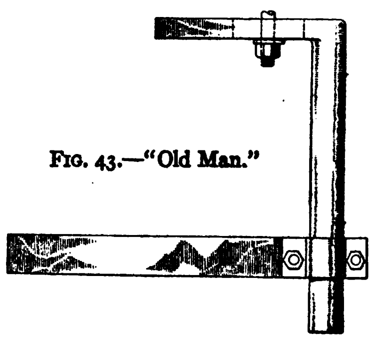


FIG. 43.—"Old Man."

Eye Goggles (Fig. 44): These are used by the Chippers and Caulkers or other men who are doing similar work as a protection against injury to the eyes. There are a number of designs, but any ordinary goggle is all right for this kind of work.

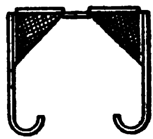


FIG. 44.
Eye Goggles.

"C" Clamp (Fig. 45): This is used by the Erectors or Plate Hangers and Regulators. It is designed to fasten the edges of two plates together and can be set up tight by means of a wrench on the head of the bolt.

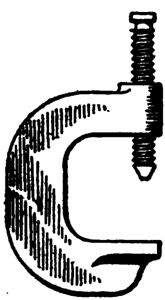


FIG. 45.
"C" Clamp.

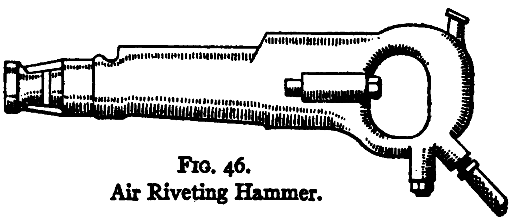


FIG. 46.
Air Riveting Hammer.

Air Riveting Hammer (Fig. 46): This is used for driving rivets, the quick action of the hammer forces the hot metal into the rivet hole and forms the point of the rivet before it has much time to cool off. It is commonly spoken of as an "Air Gun." Catalogue numbers are used in reference when speaking of the size of hammer. Running from No. 40 to No. 90, the size most commonly used being No. 50 for $\frac{3}{4}$-in. rivets, and No. 60 for $\frac{7}{8}$-in. rivets. The hammer is operated by a strong air pressure, released by the trigger (shown on top of the handle).

Plunger (Fig. 47): This is a steel plug which is a "go-between" for the hammer and the rivet die. It works loose in the air gun and drives on the end of the die. This plunger is loose and should be carefully handled by the inexperienced man as it can be shot out of the gun with sufficient force to badly wound another workman, if it should hit him. To be sure of it, many of the riveters carry it in their pocket, when not in use.

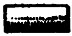


FIG. 47.
Plunger.

Rivet Die (Fig. 48): The rivet die is also a loose member of the Air Riveting Hammer family, The stem of the die coming in contact with the plunger in the hammer, transmits the blow to the rivet and forms the point of the rivet according to the shape of the die. The die shown in this figure is for a "Button Point."

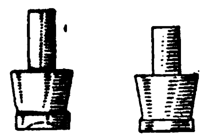
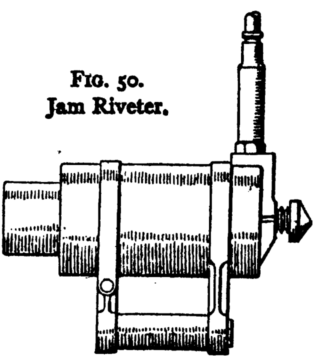


FIG. 48. FIG. 49.
Rivet Dies.

Fig. 49. This die is similar to Fig. 48, but is used for a "Countersunk Point," often called "Flush."

FIG. 50.
Jam Riveter.



Jam Riveter (Fig. 50): This riveting machine is used where it is possible to place the butt end against another part of the structure. This takes the bearing strain off the riveter and he can do considerably more work under these conditions, but

it is seldom that this type of riveting machine hammer can be used on the general run of shipwork, because of the fact that it needs a back-up.

Air Holding-on Machine (Fig. 51): This is used by a holder-on who backs up the rivet on the other end from the riveter. The extension pipe with a set

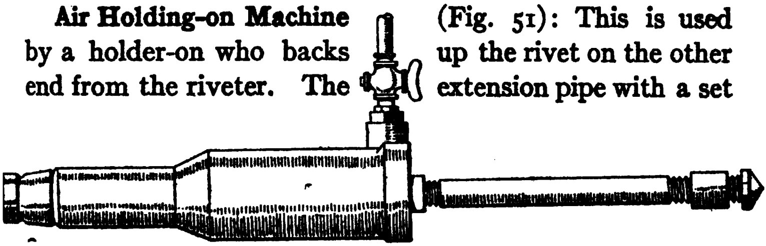


FIG. 51.—Air Holding-on Machine.

in the end fits directly against another part of the Hull structure and takes the force of the blow. Air comes in through the side and is under the control of the operator, and forms a cushion for the blow. The die in the end varies according to the kind of rivet being used.

Bevel Holder-on Die (Fig. 52): These are fitted up either pan head, concave, or flush, according to the type of rivet and are used in odd corners where it is impossible to handle an ordinary tool which is square to the surface (shown "pan head").

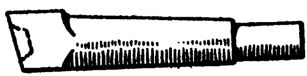


FIG. 52.

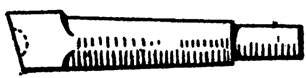


FIG. 53.
Bevel Holder-on Dies.

Fig. 53. This tool is similar to Fig. 52, but is faced for a "Button Head" rivet.

Rivet Heating Tongs (Fig. 54): These are tongs which are used by the Heater Boy at the rivet forge putting rivets in and taking them out of the fire.

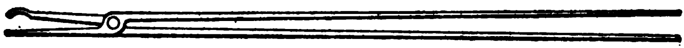


FIG. 54.—Rivet Heating Tongs.

Passing Tongs (Fig. 55): These tongs are used by the Passer Boy in relaying the rivet and when putting it in place in the rivet hole.

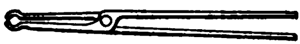


FIG. 55.—Passing Tongs.

Catching Cans (Fig. 56): These are used by the Passer Boy to catch the hot rivets as they are thrown to him by the Heater Boy near the forge fire.

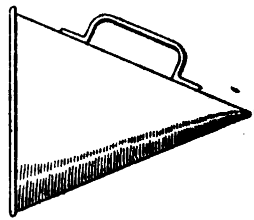


FIG. 56.—Catching Can.

"Y" Leader Hose (Fig. 57): Air hose for the riveter is generally branched for two leads. The main hose from the manifold is $\frac{3}{4}$ in. (rubber) and this is fitted to a "Y" which has a $\frac{3}{4}$-in. and a $\frac{1}{2}$-in. outlet. The larger one is carried to the riveting hammer and the smaller is

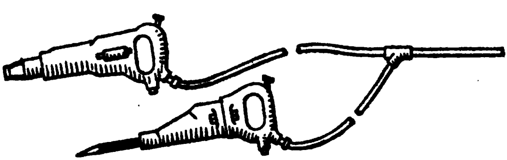


FIG. 57.—"Y" Leader Hose.

carried to the chipping hammer, This branch is about 8 ft. long, giving sufficient length for working without having too much hose to drag around.

Air Chipping (or Caulking) Hammer (Fig. 58): This is similar to the Air Riveting Hammer except that it gives a lighter blow and is used for a different purpose. When any of the plates have a ragged edge or a part must be chipped off, this hammer is used. It is also used with caulking tools when that work is done after the riveting has been finished. The riveters use this hammer as part of their outfit when driving flush rivets, the stock of which is too long. After forming most of the point of the flush rivet, the excess (called the "Rag") is chipped off while still hot and the remainder of the material finished by the riveting hammer, before it has had time to cool off until hard.

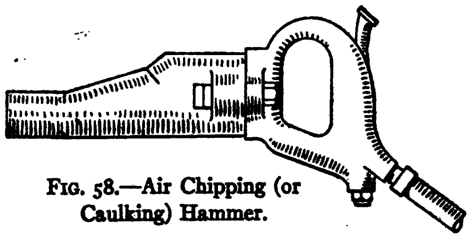


FIG. 58.—Air Chipping (or Caulking) Hammer.

Hot Chisel (Fig. 59): This is used in an air-gun to cut off the excess on the point of a flush rivet. When driving a flush rivet, the length of the rivet must be exactly right and the riveter must be on the safe side, so when the rivets are not just the length required, he will use those which are a little too long and then cut off the excess, called the "Rag."

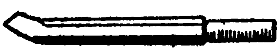


FIG. 59.—Hot Chisel.

Backing-out Punch (Fig. 60): This tool is used by riveters when it is found necessary to remove a rivet. The head of the rivet is cut off or burnt off and then the rivet is driven out through the hole by means of this punch, and a hand hammer.

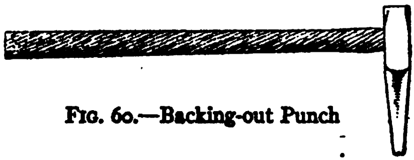


FIG. 60.—Backing-out Punch

Backing-out Countersunk Die (Fig. 61): This tool is used for backing-out countersunk rivets, the shape being adapted to the countersinking.

FIG. 61.—Backing-out Countersunk Die.

Die Socket (Fig. 62): This socket is used in conjunction with the backing-out die, Fig. 61.

FIG. 62.—Die Socket.

Tomahawk (Fig. 63): This is a blunt-nosed backing-out punch and is used sometimes in place of the sharper-nosed punch, as shown in Fig. 60.

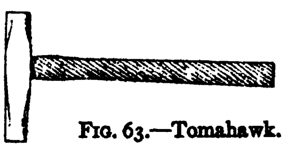


FIG. 63.—Tomahawk.

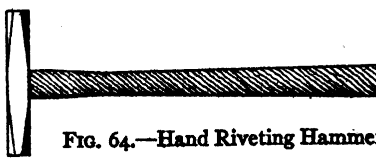


FIG. 64.—Hand Riveting Hammer.

Hand Riveting Hammer (Fig. 64): This hammer is used for riveting by hand when the work is of such a nature as to require handwork rather than the use of an air gun.

Gooseneck Dolly Bar (Fig. 65): This is used for hand work when holding-on for the riveter, in corners or some

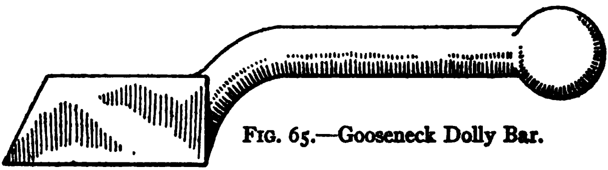


Fig. 65.—Gooseneck Dolly Bar.

places where there is little space behind the rivet. The tool weighs about 30 lb. and is used when the space is small and the air holder-on can not be fitted.

Straight Dolly Bar (Fig. 66): This is similar to the one shown above but is used when it is possible to get in

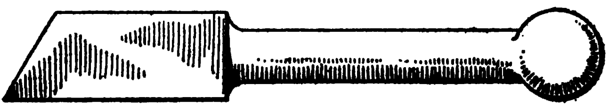


Fig. 66.—Straight Dolly Bar.

line with the rivet yet not convenient to use the air tool. (Both of these tools have different types of heads for the different kinds of rivets; as flush, button, and pan head.)

Rivet Forge (Fig. 67): This is used for heating rivets. It is a round pot of thick, cast iron, mounted on legs with a connection for an air hose. There is a portable tray above the air blast which forms the bed for the coke. Air passes up through the fire by means of numerous small holes in the tray. When the heater boy wishes to clean his fire, he turns on the air-cock wide open and the draft shoots the small cinders up out of the pot.

The sketch shows two handles which are used when hoisting the pot around on the ship. When the pot is to be cleaned, it is turned over on its side and dumped on deck. ("Cleaners" sweep up the cinders and carry them off the ship.)

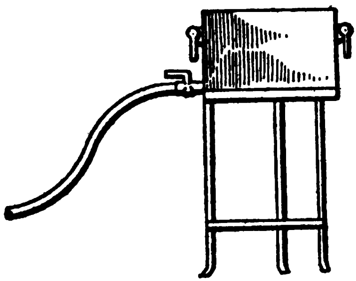


FIG. 67.—Rivet Forge.

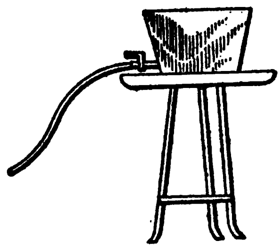


FIG. 68.—Rivet Forge.

Fig. 68. This forge is similar to Fig. 67, but is made with a smaller fire pot and is of lighter construction. It is more easily handled and does not carry so large a fire.

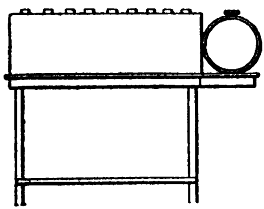


FIG. 69.—Rivet Forge.

Fig. 69. This oil rivet forge is shown as a sample of some now in use. The advantage which this type has over the coke-burning forge is in the handling of the fuel and the constant heat which is so easily controlled.

Rivet Testing Hammer (Fig. 70): This hammer is used in testing rivets to ascertain if they have been driven so that the material of the rivet completely fills

the hole. It is customary to lightly hit the head of the rivet with the hammer at the same time that a finger of the other hand is placed on the side of the rivet head and also against the plate, thus enabling the tester to detect any motion between the two.

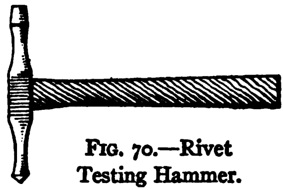


FIG. 70.—Rivet Testing Hammer.

Red Lead Gun (Fig. 71): This is a barrel with a screw plunger at one end and a $\frac{3}{8}$-in. pipe, with a nut, at the other end. When a leak is found and it is impossible to caulk it, due to the location, a $\frac{3}{8}$-in. tap is drilled and threaded, the "gun" filled with red lead putty. The gun is screwed into the tapped hole, plunger then screwed into the gun, thus forcing the putty out and into the space between the plates, or plate and angle, where the leak occurs. The $\frac{3}{8}$-in. hole is then filled with a metal plug, the putty hardens and stops up the leak.


FIG. 71.—Red Lead Gun.

Plunger (Fig. 72): The plunger of the Red Lead Gun has one end threaded to suit the inside of the barrel of the gun and the other end is square to fit the hand wrench, used when turning the plunger.

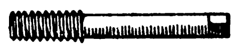


FIG. 72.—Plunger.

Hot Cutter (Fig. 73): This is used for cutting hot metal by means of a heavy maul, when doing hand riveting, or other work.

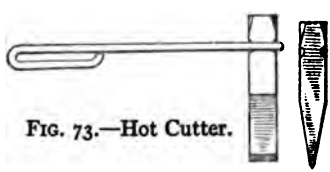


FIG. 73.—Hot Cutter.

Side Cutter (Fig. 74): This tool has a bevel edge and is used for side cutting with a hand hammer.

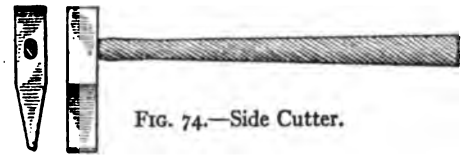


FIG. 74.—Side Cutter.

Cape Chisel (Fig. 75): This tool is used in an air hammer by chippers and caulkers for chipping work.

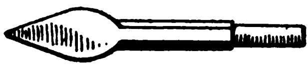


FIG. 75.—Cape Chisel.

Side Cutter (Fig. 76): This tool is used in an air hammer for chipping.

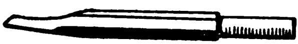


FIG. 76.—Side Cutter.

Straight Caulking Chisel (Fig. 77): This tool is used for ordinary caulking work where it is easily reached, and all straight work.

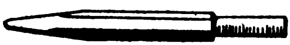


FIG. 77.—Straight Caulking Chisel.

Bent Caulking Chisel (Fig. 78): This is used for caulking in places which are difficult to reach with the straight chisel.

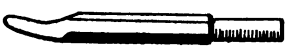


FIG. 78.—Bent Caulking Chisel.

Fine Caulking Chisel (Fig. 79): This tool is used for finishing and is also used for light work.

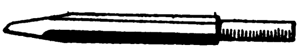


FIG. 79.—Fine Caulking Chisel.

Roughing Chisel (Fig. 80): This is similar to Fig. 77, except the face is knurled.

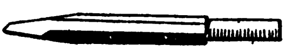


FIG. 80.—Roughing Chisel.

Roughing Chisel (Fig. 81): This bent chisel is similar to Fig. 78, except the face is knurled.

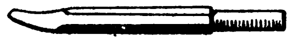


FIG. 81.—Roughing Chisel.

Roughing Chisel (Fig. 82): This chisel completes the set of Roughing-in tools which are used for preliminary work when the edge of the plate or angle is in poor condition for caulking. This tool (Fig. 82), has a rounded end, knurled, and is used before tool No. 79.

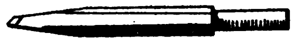


FIG. 82.—Roughing Chisel.

Straight Fuller (Fig. 83): This machine tool is used for finishing up a caulked joint on straight work.

FIG. 83.—Straight Fuller.

Bent Fuller (Fig. 84): Similar to Fig. 83, but is used for finishing up caulking when the air-gun must be held at an angle.

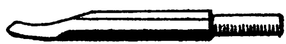


FIG. 84.—Bent Fuller.

Ripper (Fig. 85): This is used for opening up a seam or any straight line cutting in a steel plate.

FIG. 85.—Ripper.

Gouger (Fig. 86): This tool is used for destroying a rivet point, before backing out the rivet, or other similar work.

FIG. 86.—Gouger.

Bobbing Tools (Fig. 87): This machine tool is used for smoothing out surface work when caulking. It is a straight tool with an extra piece of rub-

FIG. 87.—Bobbing Tool.

ber hose (usually added by the operator) for a handle.

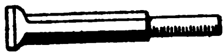


FIG. 88.

FIG. 89.

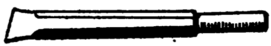


FIG. 90.
Bobbing Tools.

Fig. 88. Used by caulkers for caulking straight work.

Fig. 89. This tool is used similarly to Fig. 88 on rounded work.

Fig. 90. Another machine tool used for caulking, particularly on bent work.

FIG. 91.—Cold Chisel.

Cold Chisel (Fig. 91): This is a hand tool used for any general work required, as it is like the ordinary cold chisel.

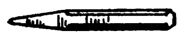


FIG. 92.
Center Punch.

Center Punch (Fig. 92): This is the ordinary type used for marking the center of a hole to be drilled or punched.

Straight Caulking Chisel (Fig. 93): This tool is used for hand work on straight caulking. (Straight means where the work on the seam is all clear and easy to do, as regards any interference from other parts of the ship structure.) Similar to Fig. 77.

FIG. 93.
Straight Caulking Chisel.

Bent Caulking Chisel (Fig. 94): This hand tool is used for odd corners, around angle bars, under foundations, etc., where the straight hand tool would not work.

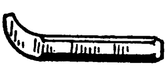


FIG. 94.
Bent Caulking Chisel.

Fine Caulking Chisel (Fig. 95): Used for finishing or light work. (These hand caulking tools are often used for testing tanks when the tank is full of water and leaks appear at different places. The hand caulking workman then travels over all the small leaks, and is able to caulk the metal by a few blows at a time, having more control over the caulking iron than when it is operated by air.)

FIG. 95.
Fine Caulking Chisel.

Diamond Point Chipping Tool (Fig. 96): This hand tool is ground down to a diamond point and is used for chipping a groove.

FIG. 96.—Diamond Point Chipping Tool.

Gouge (Fig. 97): This hand gouge is used for groove work giving a flat surface and is often used for a deep cut.

FIG. 97.—Gouge.

Cape Chisel (Fig. 98): Used like Fig. 97 for a finer cut.

FIG. 98.—Cape Chisel.

FIG. 99.
Straight Fuller.

FIG. 100.
Bent Fuller.

Straight Fuller (Fig. 99): This hand tool is used to finish up a caulked seam.

Bent Fuller (Fig. 100). This is used for finish work when the seam is in a location which is difficult to reach with a straight fuller. (Both of these Fullers are used for light work when a mere tapping is all that is necessary. They are more easily handled and more sensitive than the air tools.)

Hand Fuller (Fig. 101): This tool is used with a heavy maul for creasing plates where a sharp knuckle is required. It is often used after the plate is in place on the ship. (Sometimes an acetylene torch is used to heat the plate locally, just where the knuckle is to be made.)

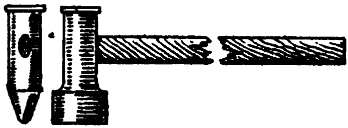


FIG. 101.—Hand Fuller.

Hand Flatter (Fig. 102): This is used to reverse the action of a Fuller. When a plate is accidentally creased or a correction is to be made, the Flatter is used to straighten out the plate and make it flat. A heavy maul and sometimes an application of heat is used, the same as when using a Fuller. (Both the Fuller and the Flatter will form the plate and make a finished job, whereas, if the maul itself were used, to come in contact with the plate, the plate would soon be scarred and present so poor an appearance that an inspector would not pass it.)

FIG. 102.—Hand Flatter.

CHAPTER IV

Shipway

Most of the shipyards have sufficient breadth of water surface so they are able to launch their vessels end-on (stern first) but some of the shipyards are located on narrow rivers or creeks where they are not so fortunate in the space needed and they must lay down their work so the vessel may be launched sideways.

It is customary to launch end-on where possible so the description of the Shipway will be for that arrangement.

The Shipway is the cradle or platform on which the hull of the vessel is laid down and from which the completed ship is finally launched into the water.

The shipways generally consist of a wood deck of planking carried on piling, where the ground is soft, for the whole length of the ship, or where the ground is firm, for the inboard end, under the bow.

The foundation is laid out in rows of piles or "bents" extending across the shipway and surmounted at the top by a heavy head "stringer" which is carried level. These bents vary in height according to the inclination of the ways and are spaced at a constant distance (see Fig. 103) according to the weight of the ship as heavier ships require a distance between bents to be less than in vessels of smaller dimension.

The main framing, longitudinally, consists of two heavy stringers approximately 3 ft. apart, equidistant from the center line of the shipway and extending the full length. The deck used for walking space is carried

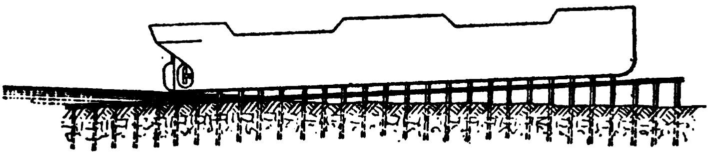


FIG. 103.

in a line with these stringers and is spiked securely to the top of the cross bents.

The outboard or water end of the shipway is carried down to the ground about high-water mark in order to have the extreme outer end below the high-water mark and to reduce the height of the inboard or bow end where the piling has been put in for the foundation.

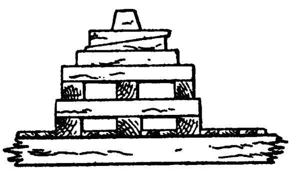


FIG. 104.

On these two main stringers near the center line are laid the keel blocks. These keel blocks are built in size according to the weight of the vessel to be carried. (See Fig. 104.)

These blocks are built up to give the required height between the bottom of the ship and the deck of the shipway. It should allow a man to stand underneath the bottom of the ship and use the air-riveting hammer and do the other work of caulking, chipping, etc., without having to stoop too much.

As all vessels must be built in a position from which they can be easily launched into the water, it is necessary to have them inclined so that they can be readily moved by sliding.

If they were to be built level, force would have to be exerted to move them into the water, but with the inclination provided, they will move of their own accord.

The inclination given to the shipway varies with the weight of the ship to be built and launched; it is from $\frac{1}{2}$ to $\frac{3}{4}$ in. per foot.

In some shipyards where the vessels are launched into a river having a swift current, it is necessary to give considerable inclination to the keel blocks so that the speed of the ship when launched will be sufficiently fast to enable her to move quickly into the stream before the current of water can twist the boat on the shipway.

In most of the shipyards, this is not a necessity, as the launching is different in tidal water. The time of launching is arranged to take place at exactly high tide when there is the greatest depth of water and it is stationary.

Under the heading of "Launching," the necessity of the wedge blocks will be clearly shown. The cap block on top is beveled to an inclination which gives a line parallel to the inclination of the shipway. (The keel blocks stand vertical.)

After the ship carpenters have given the required beveling according to the sight laid out by the shipyard engineering department, the engineers also furnish the

carpenters with a sight for a center line which is struck down the middle of the line of cap blocks.

This sight line is scrieved out into the top surface of the blocks, across the edge, and a little down the sides, in order that the exact point of center line can be determined when standing below and looking up at the bottom of the keel plates.

Spur shores are set against the back side of the cap block down to the forward side of the next bottom block. These are to prevent sliding motion of the blocks downhill as the keel is being laid.

The mid-ship point of the ship is laid on the shipway by the engineers and the "dead-flat" mark is established on the stringer by a cross mark.

Sometimes the ship carpenters will set up joists as a "monument" to give the exact location for the first keel plate, having a monument at one end and two or three on one side; thus locating exactly the right spot in a fore and aft line and the side monuments giving the exact center of the first keel plate as marked on the line of the keel blocks.

Some shipyards use pin shores for supporting the bottom plating and in this case many of these are cut from the upper end of piles, stripped of the bark, measured for the right length and laid away until ready for use. To get the proper height, double wedges are used at the lower end of the shore and these are also made and stored away until ready for the laying of the keel.

Other shipyards have "spalls" consisting of a heavy plank carried out on each side of the keel blocks and

supported at the outer end by an upright. These spalls are fastened to the keel blocks and extend the full breadth of the vessel. (For both systems, see Fig. 105.)

For rapid work, this system of using spalls is preferred as it is possible to lay considerable of the bottom of the shell plating nearly in the place where it is to be finally located and can be done before the actual work of laying the keel is commenced. These spalls are later replaced by shores, which can carry more weight than the spalls.

Where the system of pin shores is in vogue, the bottom plating cannot be laid until after the keel has been placed

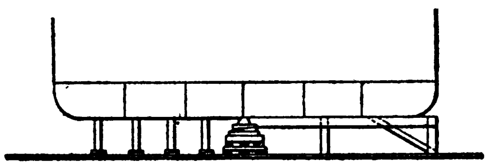


Fig. 105.

on the keel blocks, thus delaying the work and sometimes making it rather hazardous because, unless the tops of the pin shores are secured by a heavy nail or spike through a rivet hole they are apt to become dislodged by a jar and fall down on the shipway thus leaving that part of the bottom of the ship unsupported.

The method of handling material while building the ship varies in yards according to the size of work, amount of capital first involved when building the yard, and other considerations. Some shipyards have a system of overhead traveling crane running the whole length of the

shipway and extending in line sufficiently far so that any bulkheads which have been built on the ground can be raised and carried over the boat and lowered directly into place. Another method employed has a line of steel towers on both sides of the shipway which carry a " stiff-leg " derrick; in this case, there would be three or four of these towers on each side of the ship varying with the layout of the vessel. Other yards have different systems according to the layout of the ways and vary more or less in a modification of these two types.

Some of the more recent yards have covered in their shipways by a light steel roof; thus providing the workers with a chance to continue in stormy weather.

Some of the western shipyards are fitted with cable-ways which consist of a series of wire ropes and run parallel directly over the two sides of the ship, each pair of cable-ways being separated at the two ends of the boat by tall masts well supported by back stays. An electric motor operates the traveling block which can carry and deposit the steel plates as desired. When the material is to be laid they are sometimes both used at the same time, each carrying a part of the load; in this way, all parts of the ship can be reached and it facilitates the rapid handling of the material.

The air hammers and drills are supplied by an air main of steel piping which is carried along on each side of the shipway with branches running up the side of the boat and leads going in onto the deck. These air mains are supplied with manifolds on the shipway; usually about four or six on each side of the center line for use on the

bottom plating. Manifolds are fitted where the branches lead in onto the decks and these are fitted for a number of hose couplings. Each manifold has shut-off valves. (The rubber hose leading from this manifold to the riveting hammers and other air tools has been taken up under "Shipyard Tools.")

In order to make it convenient for work on the outside of the ship, it is necessary to surround the boat with "staging." This consists of two uprights (built up of square timber), the space between has a spall with one end hanging out like a cantilever beam. On the outer end of this spall, two staging planks are laid, upon which the men can walk or stand at their work. This staging is placed about 16 ft. apart along the ship so that the planks can run from one stage bent to the other and can have a little additional length for overlapping.

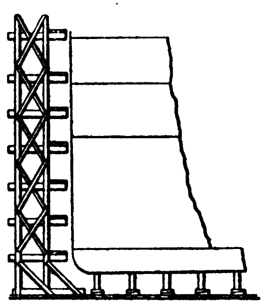


FIG. 106.

The staging generally is built in two or three sections, according to the height, and the spalls are placed about 6 ft. apart (vertically) so that a man can easily work on one plank without interfering with the one over his head. In this way, it is possible for the men to reach any part of the side of the shell plating as these spalls extend close to the ship's side. The spalls are portable and can be raised or lowered as desired. (See Fig. 106.)

The staging on both sides and around the bow can

remain in position after the boat has been completed and is ready for launching but the staging around the stern must be removed in order to allow the vessel to slide down the shipway and into the water.

Access to the ship is gained either by stairways built in with the staging or else by means of a "runway." The stairways are regular stairs going as high as possible and then stopping in a landing at one of the rows of stage planking, along which the men walk until they come to the next flight of stairs.

The runway is generally made up of planks laid close together forming a platform about five planks wide and inclined as steep as possible, running from the ground, near the forward end of the ship and reaching the height of the top deck about mid-length of the ship. Cleats are nailed on at the proper distance for an easy step. A hand rail prevents workmen from being crowded off while passing each other, some going up as others pass down to the ground.

CHAPTER V

Keels

The keel of the modern cargo steamer is composed of two plates laid horizontally and riveted together. The lower or outer one is called the outer keel, the upper or inner one is called the inner keel. The outer keel is sufficiently wider than the inner keel to allow for a lap of the shell-plating.

The outer keel extends for the full length of the ship and is finished at the forward end by a "dished" or "furnaced" plate which connects directly to the stem casting.

The after end is connected directly to the stern frame and varies in shape according to the design of the stern.

The inner keel generally extends about two-thirds of the ship's length, where the greatest strength is required, and is placed in the ship as a strength member.

The keel framing is completed by adding a vertical plate, the width of which determines the depth of the inner bottom. This vertical plate is called the "keelson." These plates are the backbone of the ship structure and it is necessary when laying down the ship to have these members correct in alignment and measurement, fore and aft, as the correctness of the succeeding erection of material

will depend upon the care with which the start has been made. (See Fig. 107 and Fig. 108.)

When laying the keel, the start is made with the midship plate of the outer keel, this being placed over the "dead-flat" mark and against the monument as described in the chapter on "Shipway."

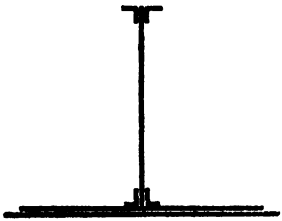


FIG. 107.

The bottom side of the plate is usually lined off with a chalk line giving the exact center line fore and aft. This line must coincide with the center line as scrieved in on the keel blocks.

The laying of this plate is followed by succeeding plates working both toward the stern and toward the stem at

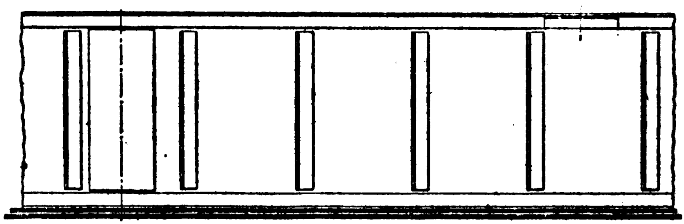


FIG. 108.

the same time, each plate being carefully laid to keep an alignment of all plates perfect. In order to retain the outer keel plates in position until the inner keel plates are laid, it is well to bolt on a small, flat plate (one bolt) at each corner of alternate plates to hold those plates

in between from sagging. To hold the plates together (lengthwise) a small angle clip is bolted (one bolt) back of the flat clip just mentioned, and a bolt about 12 in. long, with nut, is carried to a similar clip on the next plate. All of these clips are placed on the outer keel at the landing for the starboard strake so they will not interfere with laying the inner keel.

After all the outer keel is down, a steel tape should be used to check the fore and aft distance to be sure that the frame space will come right as sometimes in fabricating the plate, it may happen to be a little too long or too short and a small fraction of an inch at this place in the work will cause considerable trouble with shell- and deck-plating later on in the construction.

After the outer keel has been laid and "regulated" the inner keel is laid on it and if correctly laid out in the mould-loft, all rivet holes should come directly in line.

After these plates have been laid together, they are bolted; thus holding them securely as one piece of metal. The keelson is now ready for placing and is laid with the rivet holes of the bottom angle bars matching those in the keel plates, the location of the keelson plates being taken from the plan as sent out from the drafting room.

In many of the yards, this keelson is laid after having been partly fabricated by having the holes for floor clips punched or else the clips riveted and the keel bars in place.

It is customary to have the keelson water-tight throughout nearly its entire length and the caulking is generally done on the starboard side.

In order to insure perfect water-tightness, it is customary to use "stop-waters" at certain places where there is liable to be a chance of seepage of water due to poor workmanship or where it is difficult to caulk.

This is accomplished by placing two strings of marline the whole length between the inner and outer keel, one being between or exactly on the center line, the other one being just outside of the rivet holes in the starboard keelson bar.

Other stop-waters made of narrow lamp wick soaked in a solution, or linseed oil, are placed between outer and inner keels, at butts in the keel and across the keels at water-tight floors.

The keelson is now shored up temporarily at the top and the shipbuilders are ready to begin laying the bottom of the shell plating. The keelson plate is about 4 ft. high, according to the designed depth of the inner bottom. It is usually lap butted, treble riveted and has two angles at the upper edge and two angles at the lower edge. These angles are fitted in long lengths and have "splice bars" or "bosom" pieces at their butt joints.

CHAPTER VI

Shell Plating

A ship derives its main structural strength from its hull plating, which is divided into two main classes, bottom plating and side plating. The bottom plating extends across the bottom of the ship on both sides of the keel, while the side plating is from the curve of the " bilge " up the ship's side. Plating is laid in " strakes " the first being nearest the keel. This is often called the " garboard strake." For convenience in working it is lettered *A*, the next strake being the *B* strake, the succeeding one being the *C* strake, and so on. Each plate is numbered, as: A5S, for *A* strake, plate number 5, Starboard Side: or C9P, meaning, *C* strake, plate number 9, Port Side.

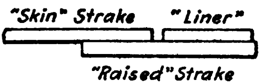


FIG. 109.

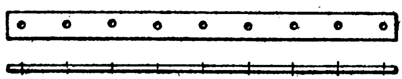


FIG. 110.

Shell plating is laid either "raised" or "joggled." The " raised " plating has every other strake against the framing with the strakes between " raised " sufficiently to overlap onto the other strakes which are often called " inner " or " skin " strakes (see Fig. 109). Fig. 110

illustrates the use of "liners" which make possible the riveting of the raised strake to the frame without drawing the strake toward the framing and distorting its shape. The space between the raised strake and the framing is filled with a small distance piece called the "liner," which is the same width as the flange of the frame, the same thickness as the skin plates and sufficiently long to run from one skin plate to the next.

"Tapered liners" are fitted on the landing or seam directly at the back of the butt-lap where one plate has been raised above the level in order to lap over the one which it joins at the end. The triangular space caused by the raising of the plate is filled by this type of liner. The

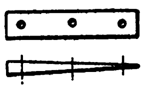


FIG. 111.

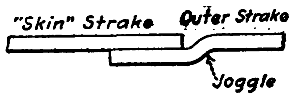


FIG. 112.

butt end of the liner is the same thickness as the strake which it fits against and tapers to nothing at the other end; the width is governed by the width of the landing or seam of the plating and the length of the liner is determined by the number of rivet holes required in it by the inspector. Usually at least two are called for (see Fig. 111).

The system of joggle plating differs from the one just described in that the raised strakes are offset when they overlap the skin strake and set directly against the framing of the ship, thus doing away with the need of a liner. The joggle or "crimp" is put into the plate by

two wheels, one out of line with the other through which the plate is forced (see Fig. 112). The edge lap is called a "seam" or "landing" and is usually double riveted. The ends of the plates are butt-lapped; when this is done it is necessary to carry the forward end of each plate underneath (inside) the after end of the plate just ahead of it. This brings the after end of each shell plate on the outside of the ship and avoids unnecessary friction as the ship travels through the water. For the same reason all rivet-

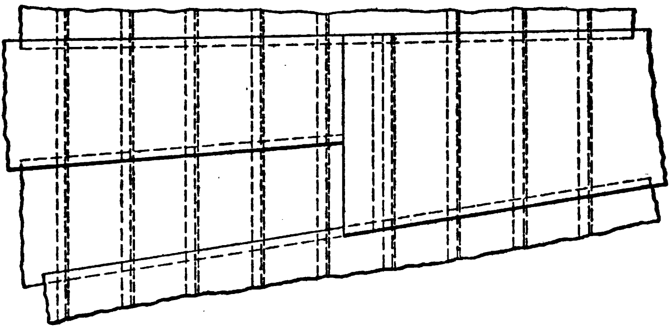


FIG. 113.

ing in the shell below the deep load line is always "pan head" and "countersunk point." The button-point type of rivet being less expensive, is often used above the waterline, where smoothness is not so necessary.

The shell plating varies in thickness according to its location, being thickest amidship and tapering in thickness toward both ends of the ship. This preserves the uniformity of strength of the ship and avoids the tendency of its breaking apart in a heavy seaway, which is always greatest

in the middle of the ship. Toward the forward end of the boat where the girth becomes less the width of the plates are contracted and usually two strakes are run into one as shown in Fig. 113. This plate is called the "stealer" and is used to prevent the plates from coming to a point. In some ships the plating is designed so that only one or two stealers are necessary and these are close to the ends of the ship and below the water line.

The **garboard** strake is next to the keel and the **bilge** strake is at the turn of the frames or the curve between the bottom and side plating. The **sheer** strake is the strake running next to the main deck of the ship. In some designs, these three strakes are given a little more thickness to increase the strength of the boat.

After the keels have been laid, the next step is to place the bottom plating starting with the *A* strake and working out toward the bilge of the ship.

Both sides of the shell plating are alike as far as location of butts is concerned, except on the *A* strake where the butts do not come in the same frame space. These butts are usually laid off to allow at least two frame spaces between butts on the *A* strake port and the *A* strake starboard. This is done to avoid a "brick shift" of butts, because of the structural strength.

This same arrangement of at least two frame spaces between butts is carried throughout the shell plating. It is necessary to have one intervening strake between butts of the two strakes each side of it. (See Fig. 114.)

Places in the shell where locally an unusual number of rivets is required, are reinforced by means of a "doubling"

plate to maintain the necessary amount of area in the material. This often happens at water-tight or other places where the rivets are close together, or when a hole is cut in the shell plate.

All butt laps are at least double riveted; the ends of the forward plates are laid on to the stem casting and

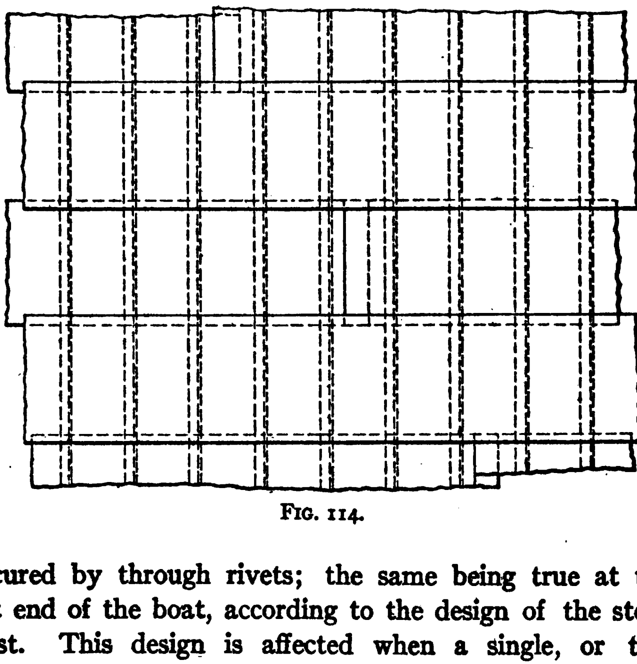


FIG. 114.

secured by through rivets; the same being true at the aft end of the boat, according to the design of the stern post. This design is affected when a single, or two propellers are required.

After the bottom plating is in place, the floors are laid and side framing erected. The Erectors (or Plate Hangers) lay the side plating, putting on the skin strakes

first and then the raised strakes. This side plating must be securely bolted in position to prevent settling, because of the weight. Whenever such settling starts, it is very difficult to "regulate" the plating higher up as the work progresses; so each plate above the bilge must be securely fastened before the next is laid.

Some ships are fitted with a "bilge keel." This is fitted on the turn of the bilge of the ship and extends for about two-thirds of the length. Its duty is to prevent

FIG. 115.

excessive rolling of the ship in a heavy sea as it catches against the water and retards the motion when the ship rolls. The usual type for merchant vessels is a Tee bar riveted to the shell plating and a medium weight of plate about 15 in. deep riveted to the standing flange. The outer edge of this plate is reinforced by a half-round iron. (See Fig. 115.)

The "oxter plate" is one of the most difficult plates in the shell plating to fit, due to its location. It is fitted just under the knuckle of the counter of the ship, where

the upper part of the rudder post enters the shell plating. This plate is usually made in a short length for easy working.

The "boss plate" which is fitted around the boss where the propeller shaft emerges from the shell, is another plate which requires expert handling.

Where the forward end of the flat keel joins the lower end of the stem casting, a plate is fitted which is difficult to work, due to the abrupt change in form, as the forward end of this plate is carried around the stem and riveted to it, while the after end is flattened to take the curved surface of the next keel plate. The extreme curve gradually dying out in the length of a few plates to the flat shape of the remainder of the keel.

These plates just described which take an excessive change in form are called "dished" or "furnaced" plates, because they are worked by a blacksmith over a fire and bent to suit a templet.

CHAPTER VII

Frames

In a ship the framing may be said to correspond to the ribs of the human body, as it resembles them both in utility and position. There are two types, "transverse" and "longitudinal."

The "transverse" system carries the main strength athwartship and prevents crushing in of the sides of the ship. It supplies the necessary strength to retain the form against the strains and stresses which occur when the ship is in a heavy seaway. The necessary longitudinal strength being supplied by the decks, shell, intercostal longitudinals and center line keelson.

The "longitudinal" system performs the same service in retaining the shape of the ship by means of girders which run lengthways of the ship. The latter system is patented and is coming into extensive use, but the transverse system is the one which is, however, most commonly used and it is the one which we will give in detail in this book.

Imagine a wooden model of the hull of a steamer, sawed into sections directly across the boat, the distance between these sections being quite close and equally spaced. When one of these sections has been removed from near the center of the ship, it will have a shape like

Fig. 116. Suppose the section near the bow is removed, it will have a shape like Fig. 117; the section near the stern like Fig. 118.

The drafting room of the Shipbuilding Company prepares a table of "Mold Loft Offsets" giving dimensions from which it is possible to reproduce transverse curves at any place in the hull of the ship. These curves are taken at points along the center line of the ship, which

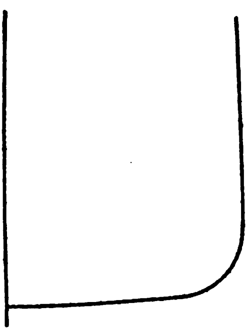


FIG. 116.

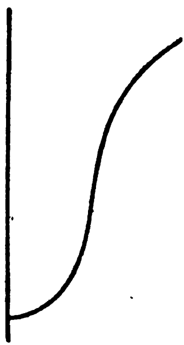


FIG. 117.

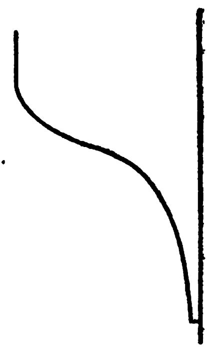


FIG. 118.

correspond to the location of the transverse frames. The Mold Loft receives this Offset Table and prepares a scrieve board for the body plan which represents all the frames drawn the full size (see Fig. 119).

From this scrieve board, the template maker furnishes templates of thin wood (about one-eighth of an inch thick) which gives the outline of the curve of the frame. There is a separate template made for each frame which varies in shape. As much of the middle body of the ship is

carried alike as possible in order to duplicate the frames in the "midship" or "dead-flat" part of the vessel.

From these wooden templates, an iron template (called a "set iron") is made of thin flat bar, duplicating the

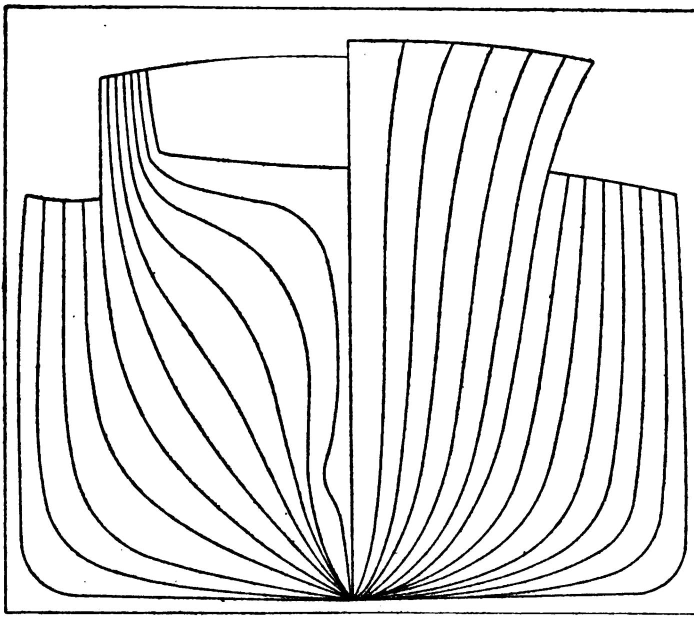


FIG. 119.

shape of the frame. It is necessary to use wood for the template made on the scrieve board. Because of the heat, the frame angle or channel can not be laid against the wood template (but a thin, flat bar can be laid on the wood without burning it), hence a steel template is made

from the wooden one and the steel template is used to form the frame.

The furnace for heating the frames is long and narrow, is heated by oil fuel and can produce a very high temperature. Directly in the front of the door of the furnace, which is at one end, is placed a "bending slab" of cast iron, made up of sections, each designed with "cross webs," giving an opening about 2 in. square. These sections are placed touching one another, forming

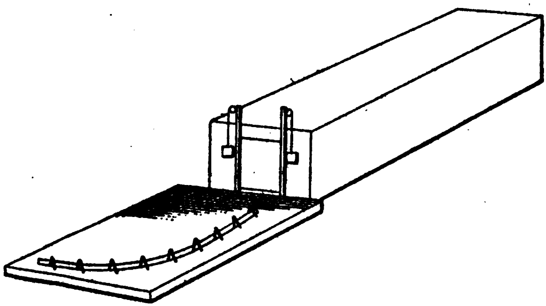


FIG. 120.

a bending slab of sufficient size to hold an entire frame (see Fig. 120).

The material to be bent to the form of the frame, whether channel bar or angle bar, is shoved into the oven and allowed to remain there until heated to a bright red color.

The steel template is secured to the bending slab by means of bent "dogs," one arm of which passes into the slab and the end of the other arm grips the template on the top surface. After the template is securely fastened

to the bending slab, the frame is drawn out by means of tongs, hauled close up to the template and the last end out from the furnace is secured against the template by means of a bent "dog" (see Fig. 121).

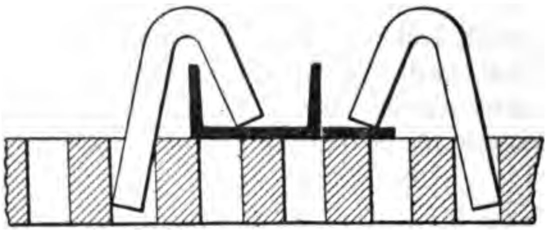


FIG. 121.

The hot frame is now bent around against the template by means of levers with a long handle having a pin on the lower side which will fit in any of the openings in the bending slab and the iron extending beyond the pin as a "cam shaped" face. (See Fig. 122.)

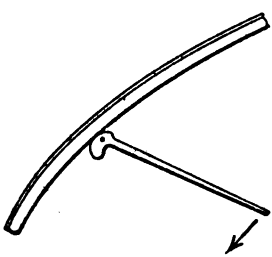


FIG. 122.

By means of this "cam," the increasing distance from the pin forces the hot frame into place.

As the frame takes the form of the steel template, it is secured in position by other "dogs," which hold it until it is cooled in that shape. After the frame is sufficiently cooled to retain its shape, the "dogs" are knocked loose and the frame is taken out into the yard, clear of the bending slab. While they are working on frames amidship, all of a similar shape, the same steel

template is retained in position. When the other frames at the ends of the ship are being bent, the templates must be changed each time.

For heavy work, on the bending slab cast-iron discs about 4 inches in diameter and about 1 inch thick are used to hold the frame angles as they are being bent.

On the bottom of these discs a short lug is cast. It is located off the center of the disc, to give varying distances from center of lug to center of disc. The lug is square in section and just enough smaller than the square holes in the slab so the disc can be easily dropped into place and removed.

The lug holding the disc, with a slight variation possible in position, according to the way the disc is held as the lug is dropped into the hole in slab, can be arranged to form any curve with other discs. The hot angle frame is forced against the side of the discs and takes its shape from the curve formed by the discs, they having been previously placed to suit a set iron or mould.

This method of shaping frame bars is used for both channel bars and angle bars.

For the type of frame common in the standard merchant boat, the channel bar is generally used at certain places in a ship structure according to the design. "Web frames" are fitted where local strength is specially required. In some designs, there is a system of "deep framing" which consists in having "web frames" fairly close together with lighter framing in between but in the standard type of boat, these "web frames" are not so common and the regular frames are carried for the length of the ship.

"Web frames" are made up of a plate and two angles, one angle against the shell facing the same direction as the frames and the other angle at the "inboard" edge of the plate riveted to it, and called a "stiffener." This angle can look the same direction as the other or not, as desired. The depth of these web frames varies according to the design and may be anywhere from 12 to 30 in. (see Fig. 123).

Sometimes a frame is made up of a deep angle, the

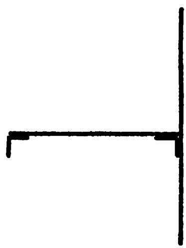


FIG. 123.

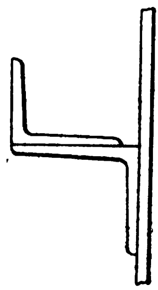


FIG. 124.

narrow flange of which is against the shell plating and a smaller angle with both flanges alike is riveted at the "toe" of the deep flange, both angles being back to back with the other flange of the smaller angle pointing in the opposite direction from the flange of the larger angle which is against the shell of the ship. This smaller angle is called a "reverse frame," is used to help stiffen the frame and often is the fastening for the wood cargo "battens" (see Fig. 124).

The usual spacing for frames of a ship about 8000 tons

is between 26 and 30 in., with a little closer spacing at the ends of the ship, coming down, maybe, to 24 in.

Because it is best to have an "open-bevel" of the flange of the angle against the shell plating, it is necessary to have the face of the angle "look" toward amidships and it is customary to carry this method of the flanges, facing each other to a certain point in the ship which is either directly amidships so that all the frames in the forward body look aft and all the frames in the aft body look forward; or the frames in the forward body look

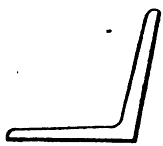


Fig. 125.

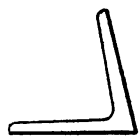


Fig. 126.

aft as far as practicable in order to keep the style of riveting in the shell plating as much alike as possible.

This "open-bevel" on the angle is necessary in order to give the riveting gang an opportunity to reach the rivet. (see Fig. 125). If the bevel is a "closed" one, it is difficult to get the rivet in the rivet hole (see Fig. 126).

It is necessary to have the ship designed in such manner that the work can be accomplished according to the equipment of the yard in which the ship is being built.

In the older type of ships, the outer plate of the tank top, called the "margin" plate, was carried out flat sufficient for the "landing," and then bent down to meet the shell plating at right angles (see Fig. 127). Many

times the frame angles were carried down through this "margin" plate into the Inner Bottom and secured to the floor.

This necessitated water-tight "staples" around the

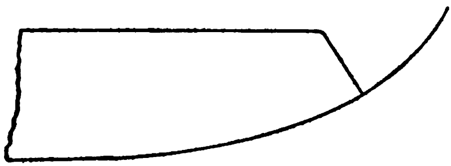


FIG. 127.

frame. This design has been altered in some of the later boats.

In the later type of "fabricated" boats where the designer keeps in mind the fact that the different parts of a ship are often made many miles apart, the "margin"

FIG. 128.

of the tank top is carried out level to the side of the shell plating (see Fig. 128) and the frames come down to the tank top and are secured to it by means of a "bracket" and "clips." (The clips are short pieces of small angle bars.)

In a design of this kind, all the structure of the floors

can be made up entirely independent of the framing and vice versa.

After the frames are erected, the "riggers" or "erectors" hold them in position at the upper end by means of wide, wood "ribbans" bolted to the frame, or with one strake of shell plating.

Frames are generally in one length, which varies according to their location in the ship. With the common type of "Poop," "Bridge," and "Forecastle," the frames run up to these decks or stop at the upper deck in way of the forward and aft "wells."

The stern of an ordinary merchant ship is round at the extreme end and is carried in a curve to the midship portion of the vessel. The "transom" frame is at the stern post of the ship and is usually built up of a solid plate or plates similar to a bulkhead. The "cant" frames are light framing attached to the after side of the transom frame and spread out like the ribs of a fan, being carried normal to the curve of the deck as far as possible. The "cant" frames are designed sufficiently strong to support the after "overhang" of the ship which is usually about 10 or 12 ft.; that is, the length of the ship aft of the transom frame is about this amount (see Fig. 129).

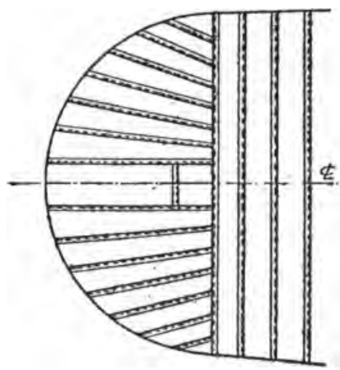


FIG. 129.

CHAPTER VIII

Floors

Directly in line with each frame there are floors built up of "girders," the depth being the full height of the Inner Bottom and extending in length from the Vertical Keelson to the side of the ship at the bilge. The floor is the part of the continuous transverse framing of the ship which is made up of two floors, one port and one starboard, one frame port and one starboard and the deck beam or beams according to the number of decks.

There are three common types of floors. The "water-tight" floor is formed by a continuous plate running from the keelson to the bilge of the ship, surrounded on all four edges by a water-tight angle bar made into one continuous piece by welding at the two corners of the inboard end and the upper corner of the outboard end. (The lower outboard part being curved to suit the shape of the ship.)

The water- or oil-tight floor has the continuous bar on the caulking side. Usually another angle called a "backing" angle is carried around on the other side of the floor, rivets through the floor plate passing through both angles. The rivet spacing on the other flange of the backing angle is not so close, as it is non-water-tight (see Fig. 130).

Another type is called a "solid, lightened" floor and

consists of a solid plate extending from the keelson to the bilge of the ship with holes cut in the plate. These holes lighten the weight of the plate by removing some of the material and also serve as access holes for workmen moving around in the Inner Bottom. In this type the angle is

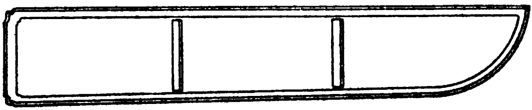


FIG. 130.

not continuous, being cut at inboard end for keelson bars (see Fig. 131.).

The third type is called a "bracket" floor and is formed by a heavy angle with a flange about 3½ ins. against the shell plating and the other flange about 7 or 8 ins. deep. The angle against the tank top of the same size, connected at the inboard end with a bracket carrying one angle

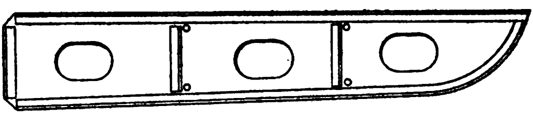


FIG. 131.

against the keelson and extending outboard about 2 or 3 ft. and stiffened at the outboard end by means of a small angle. The outboard ends of the shell and tank top angle are connected in the same way by a smaller bracket plate. Both of these plates are lightened by a circular hole. The mid part of this type of floor is held together by deep angles placed in line with the intercostal longitudinals,

to which they are riveted after the floors and longitudinals are in place (see Fig. 132).

The water-tight floors form the boundary of the different compartments in the Inner Bottom and are made water-tight or oil-tight according to the design.

It is customary to locate a solid floor at every third

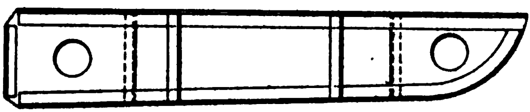


FIG. 132.

frame space with two bracket floors in between, except under engine room when all floors are solid, lightened, for additional, local strength.

The angle on the floor faces in the same direction as the frame angles against the shell plating.

The solid, lightened floors have an air vent at the upper

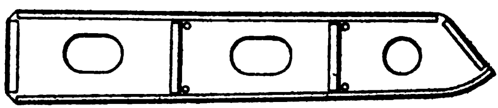


FIG. 133.

part and "limber" holes at the lower part. (These limber holes are used for passing through a "limber chain" which can be drawn a little forward and a little back, if necessary, to give free opening in case of stoppage, for draining either water or oil toward the suction pipe.)

Fig. 133 illustrates the floor of a ship having the margin plate turned down to meet the bilge, while the floors in

Figs. 130, 131 and 132 are for tank tops carried level out to the ship's side.

When erecting floors the Piping Department should be consulted, as they have to install their pipes for the "Ballast piping" system at the same time the floors are going in, as much of their piping is in such lengths that it can go into place only when *certain floors* are in the ship.

Longitudinals

There are usually two main longitudinals running from near the bow as far aft as the end of the Inner Bottom. In addition to these, there are local longitudinals under the Engine Foundation and three or four short longitudinals near the bow.

Longitudinals are designed primarily to reinforce the strength of a boat in a fore and aft direction. They are built in the Inner Bottom and are secured to the shell plating, tank top and floors; thus tying the whole part of that portion of the ship together. Taken in connection with the keelson, there are 5 main girders about 4 ft. deep (the depth of the Inner Bottom) which tend to resist any bending of the bottom of the boat.

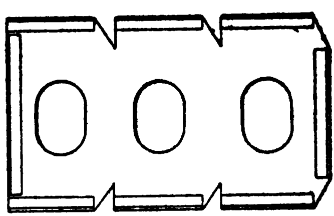


Fig. 134.

Fig. 134 shows a longitudinal made to extend between four floors.

Longitudinals are divided as continuous and intercostal, water-tight and non-water-tight, but in the case of a merchant steamer, the longi-

tudinals are intercostal and non-water-tight, allowing the compartment to extend from the center line keelson out to the side of the ship.

Any structure on the ship which must be fitted in short lengths is called "intercostal" work and as these longitudinals are fitted between the solid floors which are on every third frame space they are called "intercostal longitudinals" or for short "intercostals."

As the floors under the Engine Room are all solid,

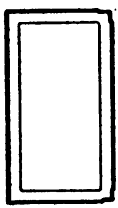


FIG. 135.

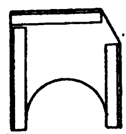


FIG. 136.

these longitudinals are fitted between each floor in that case.

A solid longitudinal between two floors is shown in Fig. 135.

The longitudinals are designed with access holes so that the workmen may travel unhindered to any part of the Inner Bottom.

Fig. 136 shows a half longitudinal between two floors. This does not extend down to the shell plating but is used to stiffen the tank top and tie the floors together.

After the flat keels and bottom plating have been laid and the vertical keelson has been bolted (and riveted if time and opportunity permit) the floors are swung into

place, and lined up, the rivet holes in the bottom plating giving the location for the flange of the shell angle of the bottom of the floor. These floors are securely bolted in place, care having been taken to place stop-waters (usually of lamp wick) between the keelson and floor angles of all water-tight floors.

The intercostals are now lowered into place, care being taken to ascertain that they make a good tight fit between the floors.

The longitudinal strength is increased by one or more

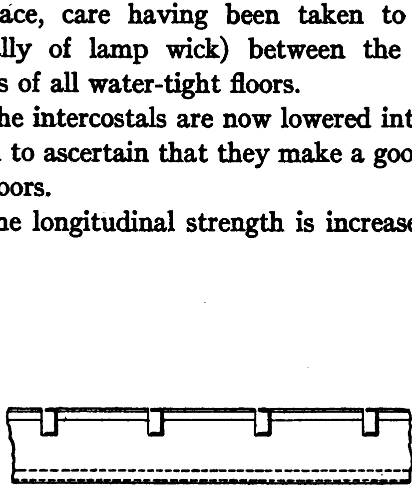


FIG. 137.

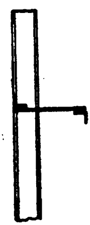


FIG. 138.

"side stringers," consisting of a narrow plate, notched out over the frames, with a continuous angle on the inner edge and intercostal shell clips (between the frames) on the outer edge. There are usually two such stringers between the tank top and lowest deck. They are secured to the transverse bulkhead on both sides by means of heavy brackets, thus continuing the strength of the stringer.

Fig. 137 shows a plan view of a side stringer.

Fig. 138 shows a section of a side stringer.

CHAPTER IX

Tank Top, Inner Bottom and Peak Tanks

The bottom of the modern steamship is built up by an inner and outer bottom, so-called. This is formed by the outer shell plating and the "Tank Top." This Tank Top is really the lowest deck, about 4 ft. above the bottom plating. The space between the Tank Top and the shell is the Inner Bottom.

The Tank Top is about the same thickness as the steel deck above and is riveted for oil-tight work. At certain places where necessary for access "Manholes" are cut in the plating just large enough to allow the passage of a man's body. A common size is 12 ins. by 18 ins. in the clear opening. These are "Flush" or "Raised," according to the location in the ship. Those being in the cargo space are flush while those in the Boiler Room are raised. The "raised" part being in the angle coaming which sets the cover up from the Tank Top plating.

Plating of the Tank Top is carried the same as for any of the decks; being laid out in strakes, with double riveted seams and butt-lats. The center line plate, directly over the keelson is called the "Rider Plate" and is always an "inside" strake, as it is the first down and because the shoring for deck beams above can be put in place as soon as needed, before work on any of the other strakes is done.

The strake against the shell plating is called the "Margin Strake." Sometimes this strake is turned down just after clearing the seam, at right angles with the turn of the bilge plating (see Fig. 139), but in some boats this

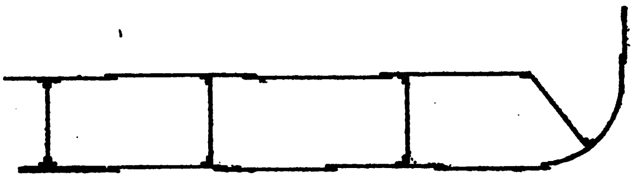


FIG. 139.

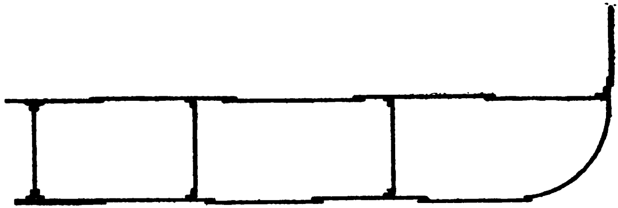


FIG. 140.

plate is carried out level to the side of the ship (see Fig. 140).

In the "Cargo Holds" the Tank Top is the flooring on which the cargo is supported.

The "Inner Bottom" is formed by the Tank Top and bottom of the Shell Plating and in a coal-burning ship: it is used for carrying water ballast when the ship is traveling "light" (with no cargo), while in an oil-burning vessel the space is devoted to carrying oil as fuel for the boilers.

The oil-tight or water-tight floors at certain intervals form the different compartments of the Inner Bottom. It is possible for a workman to travel all through the Inner Bottom by means of the Manholes in the Tank Top and bracket or open floors. These, together with the solid, lightened (access holes) floors form the third type of floor in the Inner Bottom.

When a workman is traveling around in the Inner Bottom with a candle for a light he is likely to become confused and lose his way back to the Manhole by which he entered, especially so when working on a large vessel like a battleship, but on a smaller, cargo boat this is not so apt to happen. If he is working with a "portable" electric light the cord will pilot him back to the entrance.

An Inner Bottom of this type is a partial safeguard against sinking as a hole might be stove in the bottom of any of the compartments and the ship would still be able to float. Some ships would still float if the hole happened to come on a water-tight floor, when two compartments would be "flooded." This depends on the design of the ship. Because of this possibility, battleships have the Inner Bottom carried up the side as far as the armor plate and there are six or seven longitudinals, some of them being water-tight to reduce the area of flooding and consequent loss of buoyancy. Ships of the cargo carrying type use the Inner Bottom for fuel oil or water ballast.

The Peak Tanks are two built-in tanks used for "Trimming Ship" and partly for another purpose.

All sea-going vessels are required to have a "Collision Bulkhead" in the forward end, sufficiently far from the stem to give a good-sized compartment.

This is necessary, because if the ship is in collision with another and has the bow stove in or from other causes springs a leak this bulkhead will serve to shut off that part of the ship so the water which enters will be confined to one place and not sink the vessel. To make this bulkhead as tight and strong as possible to serve its pur-

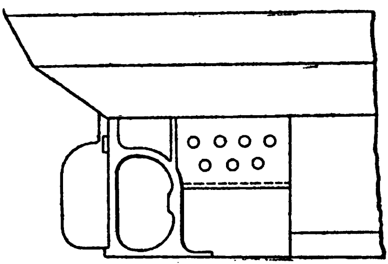


FIG. 142.

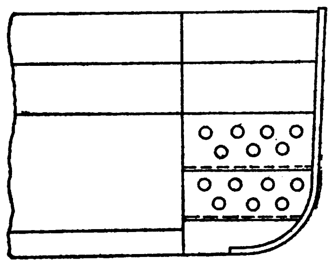


FIG. 141.

pose, it is well braced with stiffening angles and the plating itself is amply thick to help withstand any bending due to water pressure.

This space between the Collision Bulkhead and the stem of the ship is called the "Fore Peak" (see Fig. 141). There is another Bulkhead, similar in design at the after end of the ship, located a short distance ahead of the stern frame which forms another compartment, called the "After Peak" (see Fig. 142).

As the Collision Bulkhead is there partly to meet an

emergency, it follows that the Fore Peak is generally empty and dry. Both of the Peak Tanks are connected up with the piping system so they can be flooded or emptied as desired.

When a ship has the cargo stowed so that she does not set on an even keel (horizontal) it is customary to partly fill one of these tanks to load down one end of the ship so the uneven condition will be offset by the added weight of the water. This is called "Trimming ship." When the ship is "down by the stern" then water is run into the Fore Peak until she trims level. If the ship is "down by the head," water is run into the After Peak.

Because it is not always necessary to entirely fill these tanks it will often happen that they will be only partly filled and then a condition will exist which must be corrected. With free, unbroken surface the water will roll from side to side following the motion of the hull and this will tend to accentuate the rolling motion of the ship. To avoid this, "Swash Plates" are fitted in the tanks, running in a fore and aft direction, to break up the side roll of the surface of the water. These plates are fitted up free from each other, with large holes cut out of them. The plates and holes are "staggered" so they form a baffle to side rolling. By using these swash plates any amount of water can be let into the tanks without having any trouble from them.

If the ship springs a leak while there is water in the Fore Peak the water which leaks in will only join the water already there and will go no further, being held within

the Fore Peak by the water-tight bulkhead and thus still save the ship.

The piping is connected to the pump in the Engine Room so that any water that is in the compartment can be pumped out quickly, but if the leak is a bad one the water is left there until the ship makes port and can be put into dry dock for repairs.

CHAPTER X

Stem, Stern Post and Rudder

The stem of the modern cargo boat is a steel casting, in one or two pieces, about $2\frac{3}{4}$ ins. by 10 ins. of the same section throughout its length. The lower part, as it rounds down to pass under the boat, is called the "Forefoot." This steel bar is set after the vertical keelson is in place and part of the shell plating is on and riveted. The two lower bars of the keelson are spread apart sufficiently to take the width of the stem and it is fitted neatly in between these bars and riveted to them.

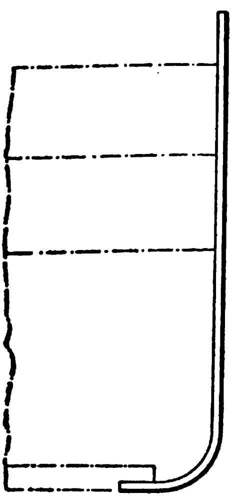


Fig. 143.

Before placing the stem casting the positions of a water line and a frame station are marked off on it by means of a wood template lifted from the Mold Loft floor, so that later the erectors will have something from which they may measure in getting the correct location to set the stem at the correct height and rake.

After the rivet holes are laid off and drilled and the

stem is ready to set up, it is raised in place by a crane and held there while bolts are passed through the bottom keelson bars and side shores are carried half way up on each side, catching angle clips which are bolted to the stem through some of the rivet holes. The side shores having the appearance of an inverted letter V. A shore on the center line, in front, will take the strain in that direction. The ship carpenters now check the position of the stem and regulate it so that when the forward plates of the shell are fitted to it the rivet holes will come in line and be ready for bolting up.

The upper end of the stem is called the "Stem Head" and is carried up above the Forecastle Deck in order to fasten it to the sheer strake of that deck or bow chock (sometimes called "apron plate"). In most ships this stem is straight above the curve at the Forefoot and is "raked" forward about 1 ft. to overcome the optical illusion which would make it look as though it was tilting backward, due to the curve of the "sheer" or outline of the upper part of the profile of the boat.

The shell plating is lapped onto the side of the stem and heavy rivets are driven clear through with a countersunk head and point so that both sides of the ship are flush.

The stem is reinforced by means of "Breasthooks" which are bracket plates directly behind the stem, carried out to the side of the ship and aft to the Collision Bulkhead, according to the shape of the bow of the vessel. These breasthooks are placed horizontally and are connected to the side of the ship by a stringer built up of a plate

and angle which runs aft in order to distribute the load along the side if the stem should ever suffer a blow. There are two or more of the breasthooks according to the design as laid out in the drafting room, and they are placed about midway between the decks. The plates of the breasthooks are the thickness of the average deck plate (see Fig. 144). These Breasthooks also serve as "Panting Stringers."

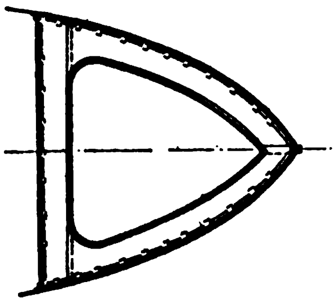


FIG. 144.

The Stern Post, or Stern Frame, of a merchant steamer varies with conditions under which she is built, as to the desirability of using a large casting and building the plating onto it or providing a smaller one and using a built up section of steel plates to continue the ending of the shell plating.

The first consideration which is taken up in a new design is the question of one or two propellers. As the majority of cargo boats, having a slow speed, are fitted with only one propeller, that is the kind in which the description of the Standard Cargo Steamer is most interested.

In passing it is well to note that in twin-screw ships the two shafts from the engines to the propellers are lined parallel with center line of the ship. Where the shaft

emerges from the shell plating, in the counter of the ship a boss is fitted, around which the shell plating is worked and a stuffing box is fitted inside to preserve water-tightness. The after end of the shaft, just forward of the twin propeller, is supported by means of the shaft strut, having the upper arm carried up, on an angle from the horizontal, to meet the counter of the ship and the lower arm carried down near the keel. These struts ending in a broad "palm" which is well riveted to the hull structure. The struts are made oval in section to pass through the water with as little disturbance as possible.

The stern frame of the single propeller (or "screw") steamer is commonly formed by a steel casting in one piece, consisting of the "Stern Post" and the "aperture" for the propeller, and the "Rudder Post." The Rudder Post is oblong in section, designed to pass easily through the water on the forward side and to carry the weight of the rudder on the aft side. The aperture is sufficiently large to allow room for the propeller blades to swing with ample clearance both for height and also between the propeller cap and Rudder Post.

The frame forward of the aperture is made long enough, fore and aft, to take the ends of the shell plating which run onto it, with a "boss" or larger, circular part where the propeller shaft comes through from inside the ship. The opening of the aperture is curved. The forward part is a large curve with a short curve at the top and a nearly straight part at the bottom. The stern post extends above the aperture and an arm is provided to extend along the keel to allow for a connection with the plating.

The after edge of the Rudder Post is "plumb" and square; and is fitted with lugs of square section, called "gudgeons," through which a vertical hole is drilled to take a "pintle" of the rudder (see Fig. 145).

Another type of Stern Frame is made up of a small casting and U-shaped plates, but it is not so strong and

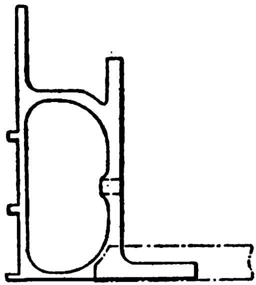


FIG. 145.

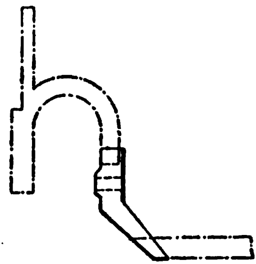


FIG. 146.

there is considerable shipfitting to get it in line. The only advantage in a frame of this kind (see Fig. 146) is in the small casting required.

The Rudder varies in shape and structure according to the ideas of the designer, but is generally made up of a "Rudder Stock" which is rounded on the forward side, has arms extending aft to take the rudder "blade," and extends up into the "rudder trunk" inside of the ship. In some designs the "arms" are shaped to take a single rudder blade or plate and sometimes the rudder has plates on both sides of the arms and is filled in between the plates

and arms, solid, with wood or other material. On the forward side of the Rudder Stock, straight hooks are cast and shaped to pass down through the gudgeons on the after side of the Rudder Post. These hooks are called "pintles" and are to take the weight and strain of the rudder (see Fig. 147).

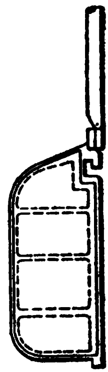


FIG. 147.

On the outside of the rudder stock there are lugs which are designed to meet others on the rudder post when the rudder is at the maximum swing. This is done to relieve the strain on the steering gear, in part, and to act as a "positive stop."

The Rudder Trunk is a box built into the hull, large enough fore and aft to allow "shipping" of the rudder stock, and is water-tight to prevent leaking of water up into the hull when the stern is deep in a "following sea." It is made of plate and angle, is caulked tight, and extends up to a sufficient height above the waterline.

The upper end of the Rudder Stock is formed to take a yoke which is operated by the steering gear. When the yoke is swung to one side or the other the whole rudder is turned by means of the rudder stock.

CHAPTER XI

Bulkheads and Hatches

Bulkheads are vertical walls dividing the ship into rooms called "compartments." They are divided into longitudinal and transverse bulkheads. These being either water-tight or non-water-tight.

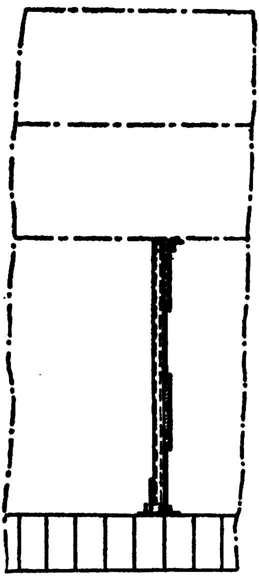


FIG. 148.

The main bulkheads of the ship are transverse and water-tight up to the Lower Deck. The water-tight bulkheads are designed to withstand the bending which will tend to distort them if the compartment is filled with water. To prevent this bending, the bulkhead plating is built on a heavy framework of either angle or channel bars, in most places the latter (see Fig. 148). These bars are called "stiffeners" and extend vertically from the top to bottom of the bulkhead, being secured to the deck above and at the bottom to the Tank Top by means of clips or sometimes by a heavy bracket (Fig. 149).

In order to connect the edges of the bulkhead, a bar

is carried around and riveted to the bulkhead and adjacent plating; that is, Tank Top, side shell and deck above. This bar is called the " Boundary Bar " and in case of the

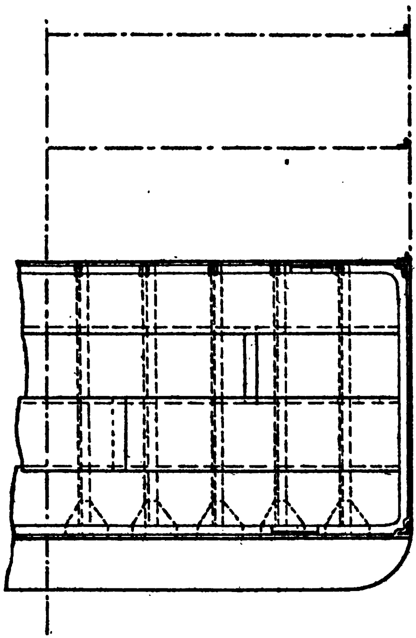


FIG. 149.

water-tight bulkheads, it is the bar which is caulked. The bottom and side edges are often reinforced by having another angle bar on the back side of this plating. This is called the " backing " bar.

In yards where the service of an over-head crane is available, the bulkheads are built on the ground just clear

of the bow of the ship. The stiffeners are laid horizontally on trestle work and the plating is placed, bolted and riveted so the whole bulkhead of plating and stiffeners are in one piece. The bars are riveted on and then the bulkhead is lifted whole by the crane, carried over the ship and put into place.

In those yards where it is not practical to build the bulkheads on the ground in front of the shipway, the bulkheads are built directly on the ship. In this case, the vertical stiffeners are set in position, secured at top and bottom and the plating hung in place. Care being taken to prevent any sagging of the plating due to loose bolting. After the plating is in position, the backing and boundary angles are put up.

To preserve water-tightness of the bulkheads, the edges of all the plating are caulked. This is done on the side opposite the stiffeners as it is impractical to carry a caulking edge under the stiffener angles. The caulking bar (Boundary Bar) of a water-tight bulkhead is "faced" in the same direction as the frame angles. This is done to allow an open "bevel" when the bulkhead happens to be at the end of the ship.

When a main, water-tight bulkhead, without any door allowing passage through it, is in course of erection, it is customary to cut an "access" hole near the tank top of sufficient size to allow the passage of a man. This hole is covered with a "patch" plate after the work in that part of the ship is complete. This is to allow free passage from one compartment of the ship to another without the necessity of climbing up over the top of the

bulkhead and down the other side. When the design calls for a water-tight door to be installed, the opening in the plate for this door is used and no other access hole is cut.

Because the lower part of the bulkhead will have a greater pressure due to the "head" of water in the compartment if the ship is leaking, the plating of the lower strakes is about one-eighth of an inch thicker than the top plates where the pressure is less. It is for this reason, also, that the stiffeners have an extra fastening at the lower end. It is customary to arrange the plating of the main bulkheads which have to take a water test with double riveted seams, and lapped butts. Care should be taken to lay off the plating so that the seams will not come too close to any "flat" or deck where the riveting would foul the deck angle.

The **Engine Hatch** consists of an opening in each of the decks directly over the engine. This is enclosed by a light bulkhead carried around all four sides from the lower to the highest deck which may be the bridge deck. Here the opening is covered by means of an Engine Room Skylight which is made portable so that it can be lifted off by means of a crane if there is any repair work to be done to the engine. On the top of the skylight, small shutters (or covers) are fitted so that they will hinge up on end and give plenty of ventilation to the engine room. For additional lighting, when the covers are closed, they are fitted with glass ports, or windows.

In order to obtain access to the engine room, a door is cut in this enclosure and a ladder is carried from there

down to the engine room floor. This door is usually on the upper deck in the bridge enclosure where it is customary for the engineering force to be located.

The **Boiler Hatch** is another opening similar to the one over the engine in that it goes up to the weather deck and is enclosed on all four sides below that deck. Opening through the enclosure gives access to the boiler room by means of a ladder. The top of this hatch is covered with what is termed the "Fidley Hatch." This is a square box-like arrangement standing a little above the deck, which allows the funnel to pass up through and is covered with grating to give sufficient outlet for air from the Boiler Room.

The **Cargo Hatches** are sufficiently large to allow ample room for handling the cargo in and out by means of the Cargo Booms.

Deck beams are cut in way of the hatches and are secured to fore-and-aft hatch girders, below the deck. The deck beams at the ends of the hatches are of extra heavy design and depth to take the additional strain off the ends of the fore-and-aft hatch girders. Some ships have the second beam beyond also of a heavier type than the regular deck beams, in order to help reinforce the framing at these places.

The fore-and-aft hatch girders of the Lower Deck are sufficiently deep to take the ends of the Hatch Strong-backs. These are generally I-beams which are portable and rest in sockets of angle iron riveted to the girders. An angle iron is carried around the Cargo Hatch, at the Lower Deck, set back from the edge of the hatch a few inches for a landing for the Hatch Cover.

Around the Cargo Hatches, on the Upper (weather) Deck a Hatch Coaming of plate stands above the deck about 3 feet, generally in the same vertical line with the beams at end of hatch and the fore-and-aft girder.

This coaming is braced strongly with pocket plates to the deck and carries a small angle around the inside, set down from the top a few inches, as a landing for the Hatch Cover.

Angle-iron sockets to receive the Hatch Strongbacks are secured to the Hatch Coaming to allow the tops of the I-beams to come in line with the Hatch Cover angle on inside of the coaming.

Cargo Hatch Covers for the design just described are generally of wood plank about 3 inches thick arranged in lengths and widths to completely cover the hatch opening. Over the Hatch Cover, on the weather deck, canvas tarpaulins are laid and secured tightly by carrying over the edge of the coaming and held against the coaming by means of Battens.

Some ships have a steel Hatch Cover hinged on either the forward- or after-end. This is built up of plates and angles, stiffened to prevent buckling and made water-tight by means of a rubber gasket on the under side, near the edge. The cover is held down by "dogs" (clamps).

These steel Cargo Hatch Covers are heavy and require mechanical means to open them. Often a steel post is located near the end of the hatch and tackles lead to the top of it or else to a nearby bulkhead.

The **Shaft Alley** or Shaft Tunnel, is a long, narrow

passage from the after end of the engine room to the after Peak Bulkhead. It is built around the " tunnel shafting " and protects the shaft from the cargo in the after Cargo Holds. The plating is well stiffened, on the inside, to withstand the pressure from the cargo and it is caulked water-tight on the outside to prevent flooding of the engine room in case of a leak in one of the Cargo Holds.

The sides of the Alley are vertical. The top is sometimes built flat and level across and sometimes it is curved. The beam stanchions at the ends of the cargo hatches rest on top of this Alley and it must be strengthened locally to carry the weight down onto the Tank Top. As the shafting for the propeller is on the center line of the ship, the shaft alley is built off center, giving ample passage for one person between the shaft and the starboard side of the Alley, as the shaft must be carefully watched and the bearings oiled (Fig. 150).

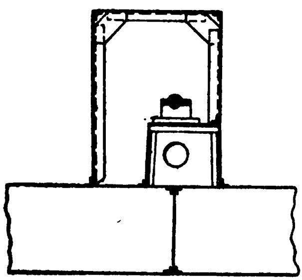


FIG. 150.

Shaft Stools or Foundations, are really steel boxes which are built to take the bearings of the different parts of the shaft, which is made up of about five lengths in the average size ship. These stools are built against the port side of the Shaft Alley, and rest on the tank top.

CHAPTER XII

Hold Stanchions; Foundations

In the Cargo Holds at the ends of the Cargo Hatches, it is customary to fit hold stanchions to support the framing in that vicinity. These stanchions are usually built up columns of plate and angle and are well secured at the head and foot. A wide bracket at the foot carried on to the doubling plate on the Tank Top carries the weight to this part where it is reinforced by extra heavy floor plates and sometimes additional stiffening by angle bars on the keelson. This carries the weight of the heavy deck beams, and framing around the hatches directly down to the bottom plating where the weight comes on the water.

Between the Upper and Middle (or second) Decks, stanchions are fitted on the center line of the ship, directly over the stanchions in the Cargo Hold. These are generally of the same type and the foot of the upper stanchion is secured to the head of the lower one by riveting through the deck plating.

Foundations might be classed as " main " and " auxiliary." The main foundations are those under the Boilers, Engine, Condenser, etc. Foundations under the Boilers are often called " Boiler Saddles " when they carry the

round "Scotch Boiler" due to the round shape, but it is a term which is commonly applied to any Boiler Foundation. These Foundations are shaped to suit the Boiler according to the design used and are well braced to withstand the tendency to move when the ship is rolling and the Boiler is swinging with the motion of the ship. The Foundations must be very strongly braced athwartship as the greater part of the motion is in that direction.

Engine Foundations are more complicated when carrying a "reciprocating" engine than for a "turbine" because allowance has to be made for a passage of the crank on the engine and it means a weakening of the girder to allow for a deep cut in way of the crank. This is recompensed by additional stiffening. In vessels where the shaft is high from the floor, the Engine Foundation must be well braced both athwartship and fore and aft. With a turbine the center of weight is much lower than with a reciprocating engine, due to the height of the cylinders in a reciprocating engine being so far above the base plate of the engine.

As much of the weight in a reciprocating engine lies in the cylinders and valves, this matter of the height above the Foundation is a very important item to be considered when designing the Foundation to withstand the effort of the engine to break loose when the ship is rolling violently from side to side.

Main Foundations are made of heavy plate and angles. The angles are riveted with countersunk points through the flange which rests on the Tank Top, as that angle must be caulked to keep the Tank water-tight. The

other riveting in the foundations is "snap." The plates are "lightened" by holes as much as possible, to save weight and for access when riveting and painting. The foundations are built to suit the general layout of the Engine and Boiler Rooms. The Walking Flat is laid afterward and brings the engineers and others at the proper height to do their work on the machinery.

The Foundation for the Main Condenser is heavily designed as this is one of the heavy items of the Engine Room installation.

The Foundation for the "Thrust Block" is strongly built in order to take the power exerted along the propeller shaft into the ship structure and force it ahead. All the power that is needed to drive the ship must be transmitted through this Foundation and for that reason it is one of the most important of the Foundations.

In the Shaft Alley "stools" are built; making a box-shaped Foundation of sufficient height to take the "steady bearing" of the Tunnel Shaft. The number of these stools varies according to the length of the "tunnel" shafting, but there is usually one on each piece of shafting, between the joints.

Auxiliary Foundations are those for the auxiliary machinery in the Engine Room such as the pumps, pipe manifolds, etc. These are either built up from the Tank Top or supported on the Frames at the side of the ship, according to the location of the different machinery which they are to carry. These Foundations are often made up of a few angles riveted to the hull structure and drilled for holding "down bolts" for the machinery.

Foundations under Bitts and Chocks on the weather decks are only " doubling plates " riveted to the deck and carried far enough to run across nearby deck beams.

Foundations under the Windlass on the Forecastle Deck are braced under the deck beams and usually supported by stanchions or bulkheads to the deck below, thus tying a considerable portion of the ship's structure together to withstand the working of the Windlass. Cargo Deck Winches are held by local Foundations but are not supported by any special stanchion.

The Foundations for all this heavy machinery on the decks generally consists of a " doubling plate" on top of the deck and additional framing (as fore and afters) under the deck to catch the " holding down " bolts in the bed plates of the windlass, winches, etc.

Foundations for the Steering Gear at the after end of the ship vary according to the type of gear installed. This is also well secured to the ship structure as there is considerable strain due to the work done in moving the rudder when the vessel is at full speed.

CHAPTER XIII

Deck Beams and Plating

Deck beams are spaced the same as side frames, there usually being one beam on each frame. These beams are of angle bar or channel bar. On ordinary merchant vessels of to-day, channel bars are often used for the heavy decks and angle bars for the lighter decks above.

Beams are connected to frames by means of "beam brackets," or "knees," which are cut the shape of a triangle and fit into the corner formed by the junction of the frame and end of the beam. They are usually connected by snap rivets with an equal number in beam and frame.

When the frame and beam are fitted, the beam usually faces the opposite direction from the frame, the bracket plate fitting between the two.

The "molded" line of the frame station is the governing location of the heel of the frame and the beam is offset from it by the thickness of the bracket.

Whole beams or "main beams" extend the width of the deck in one piece. "Half beams" are fitted in way of hatches and extend from the sides of the ship to the fore-and-aft girder of the hatch, where it is attached by means of double clips. If there is any opening or local construction which requires it, the beam is turned in the

opposite direction from the others. In this case, it is called "reversed."

It is customary to put a "crown" or "camber" in all beams on the weather decks of about $\frac{1}{4}$ in. to the foot. This is in the form of a curve. Some ships have a straight pitch with ridge on center line, and again a few ships have no camber on weather decks. Beams on the Lower Deck are carried level, without "camber."

Deck plating is laid in the same style as described in shell plating; sometimes with a "raised" arrangement of strakes and in other cases "joggled" according to the machinery and custom in the yard in which the ship is being built. Seams in the plating are usually single riveted with a double-riveted butt lap.

Around hatch corners and under foundations for deck winches, bitts, anchor gear, etc., the plating is reinforced by a doubling plate, which is generally of the same thickness as the deck plates and extends for a few beam spaces beyond the point where the extra load or strain will come. It has been customary to cut the deck plating at hatches and other openings on a radius of about 6 in., but in some of the more recent boats, the opening is carried to a sharp corner.

The center-line plate is generally laid first and the other plating is laid in strakes from that plate working out toward the side of the ship. The strakes are lettered and then each strake is numbered according to the quantity of plates in that strake. The plate nearest the shell is called the "stringer" plate. In some designs, it has a greater thickness than some of the other plates, especially

when it is on the weather deck and is in contact with the "sheer" strake of the shell plating. This combination of heavier plates at the corner of the box girder (as the ship is figured for strength) gives more material where the twisting and bending is most likely to occur.

The spacing of the riveting of the deck plating to the beams is the widest in the ship, being about 8 diameters of the rivet, which would mean 6 in. apart for a $\frac{3}{4}$-in. rivet. The riveting of the seams and butt laps have the regular water-tight spacing.

When the deck plating does not extend for the whole length, but the whole deck is covered with wood planking it is necessary to fit narrow plates (about 9 in. wide) around the ends of hatch coaming and other openings in the deck or at the end of the deck, if it is one of the raised decks, such as the Bridge or Boat Deck. This is done to allow space and material to secure the bolting for the ends of the deck planking.

The steel weather decks, according to the design, are water-tight and are caulked the same as any bulkhead or shell plate.

The arrangement and shift of butts in adjacent strakes being at least two frame spaces apart, is carried out for the same reason as described on the shell plating; that is, to avoid any weak part in the structure from having the breaks in the plating too close together.

As the drafting room generally orders these plates with only $\frac{1}{2}$ in. to spare on the width of the plate and 1 in. in the length, it is necessary to be very careful when

laying out the template on the plate so that there will be ample material to work on.

The Lower Deck is secured to the side of the ship by means of intercostal angles against the shell, between the heel of one frame and the toe of the next frame. These are called " shell chocks " or " shell angles." A " stringer bar " which runs continuously the length of the ship and catches one rivet at each frame, being riveted securely to the deck in the other flange gives additional strength. The space in between these angles and frames is filled with cement. This is done for drainage.

The weather deck is generally secured to the side by a continuous bar which fits against the shell plating as the frames stop below that deck except in way of the raised decks as the "Poop," "Bridge," and "Forecastle," where the same construction is carried on as for the lower deck.

The raised decks are generally of lighter construction than the main part of the ship, and the beams of these decks are ordinarily of regular angle bar. The plating is considerably lighter than that of the lower decks.

CHAPTER XIV

Ship Fittings

Ship fittings and shipfitting are entirely different. Ship fittings are the small articles which are fastened to different parts of the hull structure after the hull proper has been built and launched. These are in the way of equipment, both inside and outside the ship.

Shipfitting is the placing and fitting (making them fit when they do not at first fit) the small parts of the hull structure, such as angle clips, brackets, foundations, boundary bars on bulkheads, etc. Any of the work outside of "regulating" the plating after it has been erected, is "shipfitting." The process of placing ship fittings is also shipfitting work.

Boat Davits, according to a number of designs, are usually made at the Blacksmith Shop with all the small pad eyes and other things for the use of the rigger.

Rail Stanchions are màde according to the type of rail, whether of rope, pipe or top rail of wood. These are to be drilled and riveted or bolted (if fixed or portable) to the sheer strake or coaming, according to location.

Awning Stanchions, with ridges and guy ropes are usually of pipe with a fitting at head and foot, so thay may be easily "struck down."

Bitts and Chocks are bolted to their foundations,

being set in a packing of red lead and canvas between the base and the deck plating.

Iron ladders for access to various parts of the ship, gratings in Fidley Hatch, skylights over the Engine Hatch, cargo hatch battens, fittings and other small steel parts both on the outside and inside of the ship are the work of the ship fitters.

Jack and Ensign Staffs are fitted to castings on the deck or into pipe supports. The location of these flags has changed somewhat since the necessity for bow and stern guns on the Forecastle and Poop Decks during the present war.

Side Accommodation Ladders have davits and fittings for use over the side and other chocks for stowage in on deck when not in use.

Much of the work just noted is not done by shipfitters, but by ship carpenters who make a specialty of this kind of work, and are a different gang from the men who work on the shipways, on the staging and similar work.

The work on the masts and their cargo booms with all the rigging, is done by the riggers. This gang also reeve all the falls for the boat davits, flag halyards, rope rails, accommodation ladder and all other rope work about the ship.

So many types of Ship Fittings are required to suit local conditions that they are usually designed to suit the type of boat being built and detailed descriptions cannot be given. There is no set rule for ship fittings design, but it is the endeavor of all Hull Drafting Rooms

to standardize them as much as possible. The variations usually being in the size. This is true of bitts, chocks, cleats and many of the small deck fittings which will vary according to the size of rope to be used with them or some other such reason. When it is well designed the fitting will be increased or decreased proportionately in all parts. Because of this standardization, the Pattern Shop is able to store away patterns after use, until they are called for again for similar work on another ship.

Much of the work in shipbuilding is subject to standard rules regarding the structure and plating, especially if the ship is built to Lloyd's Rules, as most of them are; but in the matter of ship fittings the draftsman has a free hand for his ingenuity and inventive inclinations. Fittings are often subject to scientific calculation when proportioning their dimensions and it is the care with which the draftsman works that gives a neat, strong appearance or a rough, clumsy look to his finished product.

CHAPTER XV

Joiner Work

The .ship joiner should be more of a carpenter than the regular so-called ship carpenter, as much of his work is fine carpentry or cabinet work.

The ship joinery department has its headquarters on shore with a well-equipped shop for building doors, tables, etc. Much of the built-in furniture is portable and is so designed that it can be shipped in through doors and other openings after the ship has been built. Usually most of this work is in progress while the hull of the ship is being built, and after the launch it is possible to send a large part of the joinery work down to the ship ready for installation. Those parts which must fit within a certain space can be made an inch or so longer and then sawed off to suit the actual distance between Bulkheads.

The living quarters of a ship are nearly all furnished with built-in furniture, the chairs and tables being about the only portable articles. Most of the state rooms are fitted with berths under which are a chest of drawers, clothes lockers, and some type of wash-stand. A desk is provided for the officer's rooms. The mess rooms have dining tables and such side tables as may be necessary for serving.

The Wheel House is often completely built in the

joinery shop and put on a large truck and taken to the ship after launching. This saves much time, as the wheel house can be so completed that it can be set directly in place.

The inside joinery work, which usually consists of the paneling and other finish, is started in the shop and is put in place as soon as the various other artisans (electricians, ventilator builders, etc.) complete their parts of the fitting and are out of the way. The outside work done by the Ship Joiner is finishing around windows, hand rails, wood ladders and fittings of this type, boat chocks, paneling around front of the Bridge, wood gratings, boxes for deck gear, etc.

CHAPTER XVI

Launching

The two common ways to launch a ship are the "end on" and the "side" method. In most shipyards in the United States the "end on" method of launching is used, and only in shipyards located on narrow stretches of water is it necessary to launch ships sideways, at right angles to the keel.

When a "side launch" is necessary the ship is built on an "even keel," but when, as is the usual rule, an "end launch" is contemplated, the ship is built with the keel on an incline of $\frac{1}{2}$ in. to $\frac{3}{4}$ in. per foot, so as to be in the correct position for launching. It would be impossible to raise the ship to this incline after it is built, and unless in this inclined position the ship would not tend to move down the ways of its own weight.

Just before the ship is ready for launching, all the riveting having been done, with all the foundations for engine, boiler and auxiliary machinery in place, the compartments of the inner bottom are tested.

This testing is done by filling a compartment with water and putting on pressure by means of drilling and tapping the tank top and carrying an iron pipe about 1 in. in diameter with a funnel at the upper end to a specified height in order to give a hydrostatic head.

The outside of that compartment is then carefully

examined and any leaks which develop due to poor riveting or caulking are carefully hand-caulked and made tight. If it is not found possible to stop the leaks by this means, it is necessary to run off the water from the compartment and try to fill any space which may be open where the leak occurred by means of a "putty" gun. This gun is a large syringe which is filled with a solution like Red Lead Putty. An opening is tapped near the supposed leak and this putty is forced into the space; the opening in the angle is then closed by means of a plug and the tank again tested by filling with water. If this second trial proves a tight compartment, that part of the boat which surrounds the compartment is then accepted by the inspector.

It is customary to fit drains or "bleeder" plugs in the bottom of the ship in order to run off the water from the inner bottom compartments. This plug is screwed into place and removed from the outside of the ship when ready to drain the compartment.

Some parts of the ship structure, as decks and some bulkheads, are tested only by means of a hose with a specified stream of water. An observer stands on the opposite side of the bulkhead to detect any seepage of water through the seams or butts.

After the hull has been thoroughly inspected and passed, the outside plating is painted and the ship carpenters fit their launching ways.

The launching ways are made up of two parts; one being called "standing" or "ground" way; the other part is called the "sliding" way or "cradle."

The ground ways are made up of heavy plank built up to the necessary thickness and firmly bolted together to give a section of about 12 in. thick and about 36 in. wide. On top of this a sliding surface of oak plank about 3 in. thick is laid. On the outside edge a heavy plank is bolted, projecting above the top about 2 in. This is to act as a guard to prevent the sliding ways from running

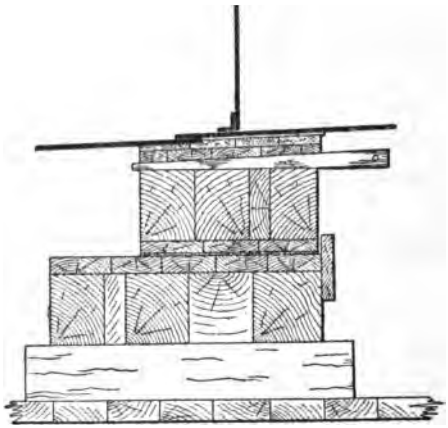


FIG. 151.

off the ground ways. These ways are built in sections about 35 ft. long and are connected by means of heavy iron lugs, bolted to the way and bent out to bolt to the adjoining lug on the next length of way. (See Fig. 151.)

The outboard (or water end) sections of the ground ways are secured in place and the other sections are held against them, fore-and-aft. To steady the ground ways

from spreading, shores are fitted at each bent of the shipway.

The outboard, or water end of the ground ways is set in place below the high-water mark by building a coffer-dam around the piling, pumping out the water, sawing off the piling to the grade set by the engineers, spiking the cross-bents to pile heads, then laying the ground ways and bolting them in place. As the outer end of the ground ways must extend sufficiently far to allow the ship to be

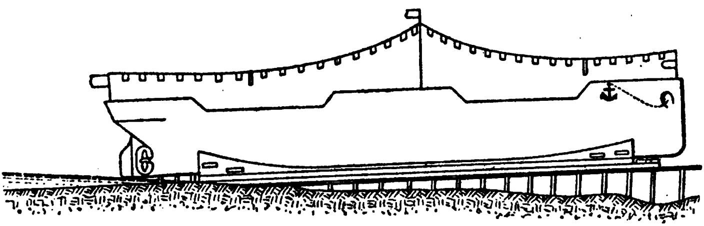


FIG. 152.

water borne as she leaves the ways, they must be carried out some three or four lengths (Fig. 152).

The ground ways are spaced about 20 ft. apart, on the outside, the distance varying with the size and beam of the ship to be launched. In some yards, the ground ways are built with a "camber" or slight rise in the mid length, to offset a tendency to "sag" when the weight of the ship is on them, and they tilt toward each other about ¼ in. (Fig. 153).

The "sliding" ways are built up in the same manner with an oak sliding surface but without any guard. They are made in sections for easy handling. After the ground

ways are in place under the ship the sliding ways are hauled up on them from the water end by means of a rope and a power drum.

Between the sliding ways and the bottom of the hull of the ship "packing" which is made up of planks about 2 in. thick by 9 in. wide is edge-bolted together for a width equal to the sliding ways. This packing is fitted to the shape of the plating, allowing for plate landings and butts, so there is an even and firm contact the full length

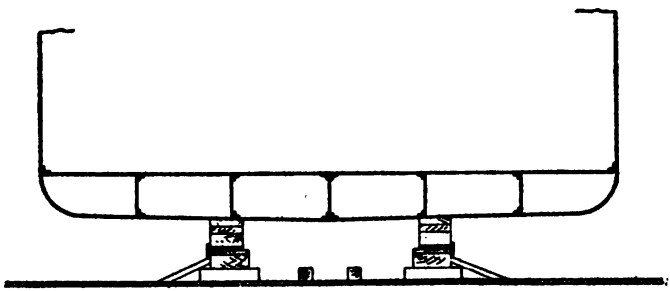


FIG. 153.

of the way. Amidships where the ship is "full" the packing is only about the thickness of the planks, but towards the ends of the ship, where it changes shape, more material is fitted in.

The cradle usually extends near the bow and stern and here the packing is so steep that heavy timbers are carried vertical and a horizontal piece is carried across outside of them. A heavy rope or chain is wrapped around the horizontal piece, down under the keel and up to the packing on the other side. This packing at the

ends is called "Poppet." Those at the forward end, port and starboard, are called "Fore Poppets," and those at the stern are called "After Poppets."

The rope, or chain, is necessary, as the steep sides of the ship at the ends would force the cradle off to the side if it were not held in place. The downward pressure on the chain draws the poppets in toward the hull and holds them in place. (See Fig. 154.)

In order to make the ways slide easily it is necessary

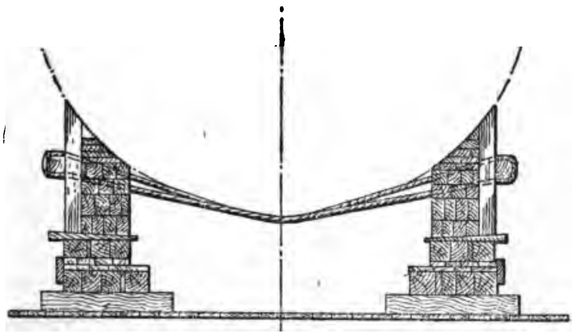


FIG. 154.

to have plenty of grease on them. This grease, with a body of heavy tallow, is floated on the top of the ground ways, about $\frac{3}{4}$ in. thick with a float and then "spacer bars" of iron, $\frac{3}{4}$ in. square and of sufficient length to stretch across the ground way are placed at intervals to take the weight of the sliding ways until time for the launch. Launching grease is applied to the bottom of the sliding ways and they are laid in position.

Between the packing and the sliding ways long wedges

are driven in at intervals of about 7 ft. These are bored with a hole through the head and a rope is passed the length of the ship, in order to be able to recover them after the ship has been launched. These wedges are counted off in groups of about fourteen in each and the heads of the wedges in each group are painted red or white, in alternate groups, so that when the men are ready to drive the wedges up to take the weight of the ship, they will know what wedges they are to work on.

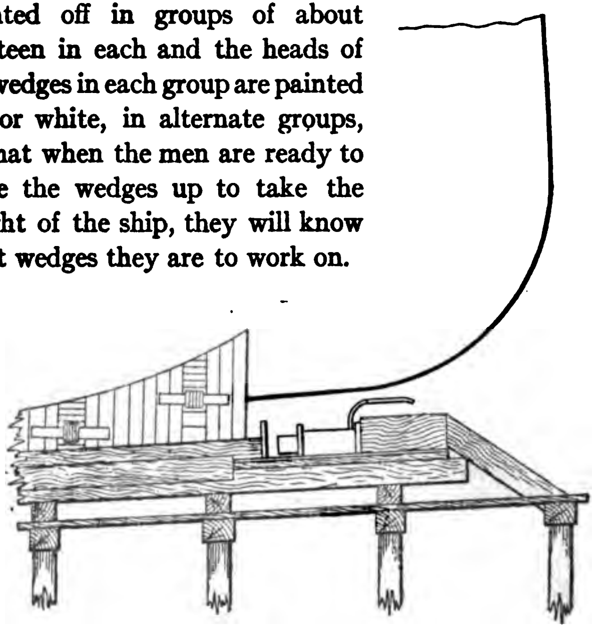


FIG. 155.

There are a number of different methods for securing and releasing the launching ways, in different shipyards of other countries, but in the United States it is a common practice to bolt a heavy oak plank, about 5 in. thick by 36 in. wide to the forward end of the under side of the sliding ways, and to the top side of the ground ways,

leaving the top of the plank clear from the bolts and end of the sliding ways enough to be able to saw it across. There are two such planks, one on each side of the ship. The line for sawing is generally marked down the sides and ½ in. intervals marked off on it, so the sawyers will be able to keep even when sawing, as it is necessary that both planks shall be sawed through at the same time (see Fig. 155).

Before the day of the launch, the marine engineering staff have fitted the propeller, hung the rudder and the ship carpenters have secured it "amidships" (in line with the keel) with two heavy wood battens. The "bleeder plugs" have all been replaced in the hull since draining off the water for testing the Inner Bottom. The necessary bitts and mooring chocks have been fitted on board and a kedge anchor with sufficient wire rope cable is slung along the bow to use in case of need when the ship is in midstream. The painters have been over every square foot of the bottom where possible to reach (as the shores are taken down, just before the ship goes overboard, the painters are just behind the workmen and paint all the places where the ends of the shores were touching and could not be painted before). The ship carpenters have removed all the staging around the stern and drawn away from the ship's side the cross-spalls and piled the staging plank on them, one wide and three high. As the side staging is parallel with the ship, it is not necessary to remove any of that. All compressed-air hose is taken off the ship, back to the stand pipes, and all ladders or anything else which touches the ship has been removed.

During the low tide just preceding the launch the tops of the ground ways which have been under water and therefore not greased, are heated with flat coke ovens to dry them off and then the grease is put on to match with that already on the ways further up from the shore. To prevent a possible "sticking" on the ways, two hydraulic jacks have been installed, one on each way, at the head, with the plungers near the end of the sliding ways. These jacks are connected up to a pump which can deliver a kick of about 200 tons for each ram. These jacks are now tested to be sure they are all ready for service, if called on.

In order to prevent sliding of the cradle beforehand, "dog shores" are fitted near the after end of the ground and sliding ways. These are diagonal braces with ends resting against lugs on the two ways. The pressure is supposed to hold them in place, but to be sure they do not drop before the time, they are supported by a small prop.

Because of the extra, local weight on the stern, due to the stern frame casting, propeller, rudder and overhang of the stern the after end of the ship must be supported for as long a time and as much as possible.

To do this "tumble shores" are fitted. They are heavy, square timbers placed close together extending from the bed of the shipway to under the keel. They remain in position after the ship has been "wedged up" and keel blocks removed; and fall over backwards as the ship slides down the ways on its journey into the water.

To allow for easy movement the edge on which the

shore will turn is rounded over from the center of the end of the shore, thus giving sufficient bearing surface but no sharp edge which will tend to cause the keel to raise by the shore pivoting as it falls.

About two hours before time for the actual launch (this time varies in different yards according to the skill of the workmen), work is started on the cradle. "**Remove Spacer Bars**" is the first order given, when all the iron bars are drawn out from between the ways, laid off at one side and counted, to be sure they are all out.

"**Dog Shore Guards Stand By**" is the next order, when the men who have been detailed to remove the dog shores are assembled and their bosses make sure that all men are accounted for.

"**First Rally on the Wedges,**" follows, when the workmen who have been previously divided into gangs of about eight men on each ram (rams are heavy oak pieces about 8 in. square and 10 ft. long, with rope handles at the side for handling) start to drive in the wedges between the cradle and the packing. A rest period for the men is followed by,

"**Second Rally on the Wedges,**" when they are again driven in and any of them which had not been driven in straight the first time have been seen by the inspectors while the men were resting and the wedges are now straightened and driven in still further. A rest period for the men again follows. Another inspection.

(Some yards have a "Third Rally" on the wedges, but other yards prefer only two rallies.)

"**Remove Joggle Wedges and Grease Covering Strips,**"

is now heard and small wedges which have held the cradle centered right are taken out and the surface of the ways greased.

"**Remove After Shores.**" This means that the shores supporting the ship by bracing against the hull, at various places are taken down, starting from the stern, for about 40 ft. forward. The men then wait for another order.

"**Remove Shores and Timber Keel Blocks.**" The remaining shores are now taken out, working forward and keeping an advance of about the distance gained on the last order (40 ft.) ahead of the men who are removing the keel blocks, starting from the stern and taking out alternate blocks.

The Tide Report is now given to the man in direct charge of the Launch, so he will know the exact condition of the water over the ends of the ground ways.

"**Stand By**" is now heard. (This is about one-half hour before the plunge.)

Some yards use cast-iron boxes with an open top and a large screw plug at one end, called "Sand Boxes." These are placed on alternate keel blocks and on the side cribs which have been built up under the bilge of the ship, four on each side. If this yard uses these boxes, the next order will be,

"**Remove Sand Box Plugs,**" when the plugs are unscrewed. A report is made that all plugs have been taken out.

"**Spoon Sand and Remove Blocking**" is the next order, when the sand is spooned out from the box and the remaining keel blocks and the side cribs are taken

down and removed out of the way of the hull when it is ready to launch.

If this yard does not have sand boxes the order would have been,

"**Remove all Keel Blocks and Cribs,**" when the only things now holding the ship from sliding are the saw-off planks bolted to the ways and the two dog shores braced against the two ways, on the outside edges.

"**Remove Dog Shore Side Braces Only**" is now heard, when the Dog Shore Guard (who are old and experienced hands at the business) carefully removes the props under the dog shores, the increasing pressure holding the dogs in place.

A final inspection is now made by the men in charge, one going along each side of the ship, and one going along the center line to be sure that all is clear.

"**Drop Dog Shores**" is then ordered, and the men detailed to look after the shores knock them down. If any of them stick, the men cut the shore with an ax until it falls down out of place. Two minutes is all that is allowed for this operation. Now come the final words:

"**Saw-off,**" and the sawyers at the saw-off planks at the head of the ways start to saw as fast as they can move, as the ship is now in a dangerous condition if anything holds her unevenly on the ways. These two crosscut saws have two men at ends of the saw (some yards have extra handles with four men at ends of the saw). A man in charge of the sawing stands between the two gangs on the two sides of the ship and counts so they will saw in unison, keeping his eyes on the advance of

the saw down the line of $\frac{1}{3}$-in. intervals which had been marked on the side of the plank. Just as the saws reach nearly to the bottom of the plank a sound of cracking and tearing of wood is heard and the ship starts very slowly, gathering momentum as she proceeds until at the time when the bow reaches the water the ship is traveling fast. A 400-ft. ship will travel down the ways in about forty to fifty seconds.

Just as the ship starts on its first journey, the sponsor in the Launching Party does her share of the work and, leaning over toward the stem, hits it a sharp blow with the christening bottle, naming the ship as she does so.

In planning a successful launching it is necessary to forestall the likelihood of two possible accidents, capsizing and tipping. There is a distance during the travel of the ship down the way when the after end of the vessel is water-borne and the forward end is land-borne on the forward end of the cradles (called "poppets"). If the ship stopped moving anywhere during the time required to cover this distance, it would capsize, as it is supported only at both ends and not in the middle.

It is necessary to have sufficient depth of water over the end of the ground ways so that the after end of the ship will be water-borne before the center of gravity of the ship passes beyond the end of the support of the ground ways; thus avoiding a "tipping." If the vessel, "tips," the stern dropping down until water-borne, the bow rises and the position of the forward "poppet" as held by the rope cable, as before described, will tend to sag and drop. Then later when the after end of the ship is water-

borne, and the bow of the ship comes back to its original position in the cradle, there is trouble if the cradle is not there to receive it (Fig. 156).

Neither of these accidents is likely to happen in a well-regulated launch, because the speed of the ship being fast and continuous, carries it through the danger space before it can start to capsize, and the drafting-room force having previously calculated a curve showing a tendency of a tipping moment and the condition which would cause this has been carefully looked into and avoided.

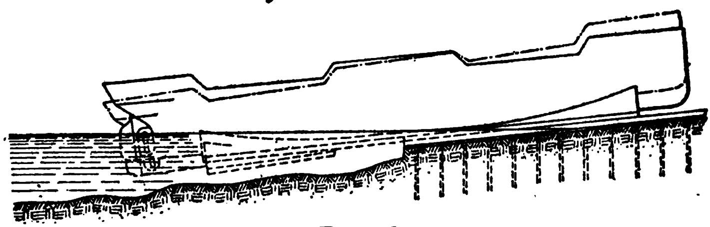


Fig. 156.

In yards where a broad surface of water is available for launching into, the ships are allowed to run free until their momentum has died away, and they may either drop an anchor or are towed back to the wharf at the yard.

Some yards,. due to the narrow space in which they are able to launch their vessels, are obliged to use different methods for checking the momentum of the ship and it is customary to either secure cables to the ship and land which will retard the progress of the boat by breaking of the cable, or to provide bundles of heavy chain which are connected to the sides of the boat by a chain pennant, causing the bundles of chains to pick up, one after an-

other and drag along the ground; care being taken to have a bunch of chains on each side taken up at the same time, in order to have the strain equal. (The writer has seen vessels launched on the River Clyde which were laid down diagonally to the shore line in order to give more distance, and these vessels when launched thus with bunches of chains would lose their momentum just after having gotten into the water.)

Because of magnetic influence it is customary to head a ship in the opposite direction after the launch and she is usually tied up at the wharf in this way.

CHAPTER XVII

Engine Room and Engines

The busiest place aboard ship is the Engine Room, for it is here that the energy generated in the Boiler Room is diverted into the main machinery that propels the ship on its voyage or into the various other machines that keep the auxiliary apparatus in operation.

The modern marine engine is now fairly well standardized and of two main types: the reciprocating, in which the motion is back and forth; and the turbine, whose motion is rotary. The reciprocating engine is still, after a great many years, in use and its cylinder, piston, piston rod, slides, connecting rod, crank and crank shaft are quite familiar to most of us. It is the crank shaft of a marine engine that is connected to the shafting in the thrust block. Marine engines of the triple-expansion type with a high, intermediate, and two low-expansion cylinders, are those most commonly employed.

Experiments in recent years have shown that, when its speed was controllable, the turbine was preferable for marine propulsion. With the use of the reducing gear, by which the propeller is made to revolve, say once for the turbine's 40 times, it has proved more satisfactory because the arrangement of turbine permits of keeping the weight low, while in the reciprocating engine the

weight is considerably higher, above the shaft, due to the weight of the cylinder, also in the amount of space required.

As the propeller must be sufficiently high to be protected from striking any stray logs or other submerged objects, it is customary to have the center raised enough so the blades during the downward swing will not go below the line of keel. This brings the center line of the shafting so high above the tank top plating that high foundations must be made to take the engine bed, rather than drop the base of the bed down, thus increasing the weight to a considerable extent. To keep the Main Condenser in line it is necessary also to have this on a high foundation. Therefore, the grating, called the "walking flat," for the engineers to stand and walk on, is raised some distance above the top of the inner bottom. The Auxiliary Machinery is raised to meet the height of the grating, and to suit the best stowage arrangement.

In some of the older shipyards it was the practice to assemble the engine aboard the ship. When this was done, it was customary to strike a center line above the bed plate, indicating the position of the center of the shaft. The columns of the engine were bolted in place, the slides fitted, and the cylinders were set. By plumbing from the top of the cylinder down through the openings, the alignment of the guides was determined. After the crank-shaft was in place, this was rotated through 180 degrees and the opposite positions of the crank gave a dimension square to the shaft. In this manner it was possible to "line-up" the engine, even though the ships were being built at an inclination on the shipways.

As a result of modern methods of handling heavy weights, it is possible and is largely the practice in modern yards, to build the engine complete in the erecting shop and then dismantle parts of it; carry it down and put it up directly on the ship. When building in the shop the bed plate is placed on a "platen," which is really a platform leveled up in both directions. One advantage in erecting in the shop lies in the fact that it is possible to use the plumbing line in both directions, and the work of the engineers can go on much faster when not surrounded by a lot of men who are still building the ship. The shop, too, has more room and better facilities for doing the work.

Turbines are made in some shipyards, but most of the the shipyards which are installing them in the ships being built in their yards are buying the turbines complete from the manufacturers. The turbines are delivered in advance and stored until ready to be placed in the ship and then fitted on the foundations made ready for them.

The engine room of the modern cargo steamship has, beside the main propelling machinery, many small engines and pumps for the work about the ship. These are taken up under the heading of "Auxiliary Machinery."

It is interesting to note the cycle of work done in the Boiler and Engine Room in order to produce the power required to drive the ship. Water is drawn from the feed-water tanks to the boilers by means of the feed pump. Here it becomes heated and turns to steam; when it is allowed to escape through the main steam pipe into the engines. In both the reciprocating and turbine

engines the steam enters at one end, called the high-pressure end, and travels through the engine, expanding in successive stages until its energy has been practically all used up. After its work is done in the engine, it is forced out into a pipe and is drawn down by suction into the Main Condenser. Here the steam comes in contact with the cold pipes, becomes condensed, and turns into fresh water again, which on all ocean-going vessels must be carefully conserved.

From the main condenser the water is pumped out by the air pump to the Feed and Filter Tank. As the engines are well lubricated, some of the oil is absorbed in the steam and carried along with it, so that when the water is run from the Main Condenser, there is more or less oil mixed in with it. As this is detrimental to the inside of the boilers, it is necessary to remove as much of this oil as possible before the water is again used as feed water for the boiler. This is the purpose of the Filter Tank. The water enters this tank, which is divided into four or five spaces by diaphragms which are open at the top, allowing the water to flow over. In each of these compartments in the tank there are " Loofa " sponges, or excelsior or some other such material. These are placed to catch the oil and grease, and after they have been in the tank for some time, they are taken out and thoroughly cleansed before being replaced.

Passing from the Hot Well end of this tank (the Hot Well meaning the end where the water is waiting to be drawn off after it has been purified) the water is often passed through another purifier in the pipe line, called

the " Grease Extractor " which is a small tank containing two cartridges. These cartridges are really a form to hold Turkish toweling which is wrapped around them and through which the water must pass on its water out of the compartment. These Turkish towels are removed and cleaned in the same way as the sponges of the Filter Tank. After this further cleansing the water is allowed to run back into the feed-water tank.

With the ordinary type of reciprocating engine, as the piston can be driven in both directions, it is possible to reverse the action of the propeller by rotating it in the opposite direction with the same engine that is used when going ahead; but from the nature of the turbine engine it is necessary to have a turbine for backing or reversing of the propeller. This backing turbine is on the same shaft as the one for driving ahead and while the ship is going ahead the backing turbine runs free. When it is necessary to reverse the motion of the shaft, the steam is admitted to the backing turbine and the other runs free.

The power developed in the backing turbine is usually about two-thirds of the power of full speed ahead.

CHAPTER XVIII

Boiler Room and Boilers

The arrangement of the Boiler Room depends largely upon the type of boilers to be used. For the coal-burning type the coal bunkers are often placed at the side or as a cross-bunker, running from one side of the ship to the other. Where the bunkers run along the sides, the one opposite to the Boiler Room has a door for shoveling coal, and coal in the other bunkers is carried through this door by means of coal buckets which run on a trolley track through the bunkers; the track being covered up and filled in when the bunker is full, but as the bunker is being emptied and becomes free, the coal can be carried to the dumping door, where it is shoveled into the Boiler Room, and is ready for use in the boilers. When this trolley track is not used the coal is shoveled by hand and this is called "Trimming the Coal."

When coal is used, ashes are hauled from below the grate and shoveled into the ash ejector if the ship is at sea. This ash ejector is a large syphon pump carrying water with an open hopper so that the ashes can be shoveled into the hopper, caught by the stream of water and washed up the pipe and out through the ship's side, above the water line. When the ship is in port, the harbor authorities will not allow ashes to be dumped

overboard and they usually are carried up the elevator, running up through the ventilator from the Boiler Room, carried out on deck and dumped over the side into a scow.

In the Boiler Room where oil fuel is used, there is a much more neat appearance, the space can be smaller and it is altogether much more satisfactory. The oil is pumped from the Settling Tank by means of the Service Pump. From this pump the piping runs along the top of the boilers with separate branches down to each door of the fire pot, so that each boiler can be independent of all the others.

There are two main types of boilers; the fire-tube and the water-tube. In the first case the fire, which is really hot gases, due to the combustion in the fire box, passes through the fire-tubes and the surrounding water which is in the boiler becomes heated. This type is usually called the Scotch boiler. The diameter is generally more than the distance along the axis. There are three fire boxes, one in the lower part on the center line and the other two just above it on the sides. These fire boxes run to the after end of the boiler, and the gases pass up through a combustion chamber and return to the front end of the boiler again through small tubes. From there the gases pass out into the Uptake and so on up into the Funnel and out into the atmosphere. In this type of boiler, it is necessary to have the top of the fire boxes entirely covered to a sufficient depth with water in order that the crown or top of the box does not become overheated and collapse. This is the most frequent trouble

arising from this type of boiler, other troubles are caused by bad joints or leaky tubes.

The other type of boiler, called the water-tube boiler, is manufactured in a number of different shapes and combinations. There are at least a half dozen of these, all of which are of good design and durability. In this type of boiler the water is carried in a number of small diameter tubes which are held in position by cast-iron headers. The water is made to flow from one layer of pipes to the next layer above it by means of diaphragms in the layers which separate one compartment from another. By this means of passing the water directly over the fire and through the gases, it can be brought to a high temperature and steam in a shorter space of time than is possible with the Scotch Boiler, because of the smaller volume of water. The fire pot, or combustion chamber, in these boilers is as low as possible and the combustion made very thorough by means of baffle plates which hold the gases around the outside of the water tubes until they have lost practically all of their heat, when they pass upwards and out through the Uptake and Funnel.

For some time past it has been customary to use the Scotch Boiler on merchant work and tramp steamers, where there was ample time to get " under way," but for men-of-war where it was often a vital necessity that they should move quickly, it has been customary to use water-tube boilers.

During war time when it is so difficult to get material delivered, etc., in time to complete the ship program,

other conditions are arising which necessitate changes from the old order of things, and water-tube boilers are also being used for cargo boats for Government service.

One advantage in using the water-tube boiler lies in the fact that this can be built aboard the ship and finished there complete while the ship is still under process of construction. When using the Scotch boiler, this cannot be done, as that type of boiler must be built in a regular boiler shop, where the necessary rolls and riveting tools can be used.

Access to the Boiler Room is by means of iron ladders from the Upper Deck and by a door from the Engine Room. With the two large ventilators at the forward end of the room giving a good draft of cool air over the heads of the firemen, and with an oil-burning installation of boilers, where the arduous work of stoking the fires is done away with, the work of the firemen in the boiler room of a modern steamer is not the struggle for an existence which was so often the case in the olden days.

CHAPTER XIX

Propellers

Propellers are made either solid (with the hub and blades cast in one solid piece of metal) or they are built up (with the hub separate from the blades). Nearly all merchant ship propellers are solid cast iron, and those for the larger men of war are built up with the hub and blades of bronze. In this type the blades have a large screw shape at the base of the blade which threads into a similar shape at the hub. Built-up propellers have the advantage of making it easy to remove individual blades for repair in case of damage, while with the solid propeller, the entire propeller becomes useless until it can be replaced. Nearly every merchant ship carries an extra propeller on deck for use in case of emergency.

As the "Rules of the Road" require vessels meeting head on to pass to the right, leaving each other on the port hand, all single screw ships are fitted with righthand propellers, since these revolve so that the head of the ship would turn to the right with the rudder set amidships, thus helping by a natural tendency what is required by law.

"Twin Screw" ships have two propellers which turn in opposite directions from each other with the tops turning outward from the ship. This working of one propeller against another makes steering the ship easy, and keeps

her in a straight course. If both propellers worked in the same direction, it would be necessary to have the rudder set partly across the ship in order to keep her in a straight course, and if it became necessary to steer the ship in that direction the rudder would not have sufficient control of the vessel. It has happened that, as a result of an accident to the rudder, the twin propellers have been used as a means of steering, but it has been found unsatisfactory because it gives the ship an uneven course due to the " wild " steering.

The inside of the propeller hub is bored with a taper and a "key-way." The piece of shafting which fits into the hub is called the " tail shaft." On the after end of this shaft a corresponding taper and key-way is made. At the extreme end of the shaft a smaller, straight part is turned and threaded to take a large nut. This nut is " acorn " shaped with the butt flat to fit against the propeller hub. The forward end of the tail shaft is fitted with a large flange and drilled for bolts.

The shafting ahead of this is called the " tunnel shafting " as it runs through the " shaft alley " or " tunnel," an enclosure built over to protect it from damage by the cargo and to provide access to the shaft at all times, whether the cargo is in the Hold or not. This shafting is in five or more pieces, according to the length of the ship. It is bolted together by heavy flanges and is supported by a " steady bearing " to each length of shaft. These are in halves so the shaft can be set down into them and the " cap " bolted in place afterward. The foundations for these bearings are called " Stools " and

they are set up about 4 ft. from the Tank Top. The forward piece of shafting is engaged with the "Thrust Block."

On this piece of shafting there are cast webs, or collars which have been machined to stand at right angles with the shaft, a few inches apart and sufficiently thick to withstand a heavy thrust. The forward end of this shafting is connected direct to the main engine in the Engine Room.

The forward end of the Shaft Alley is widened out to allow room for the "thrust block." There is a bulkhead across the rear of the Engine Room and this is continued around the "thrust recess," as the space for the thrust block is called. A water-tight door is fitted in this bulkhead for passage into the Shaft Alley. As before stated (under the chapter on Bulkheads) the Shaft Alley is built off the center line of the ship to give a passage, generally on the starboard side, for the engineers to inspect and oil the shafting.

The Thrust Block is a heavy, casting having webs corresponding to those on the shaft, as just described, but moved one space so that the collars on the shaft will fit into the spaces on the thrust block. As the propeller revolves and (due to the shape of the blades which cut ahead in the water), gives a thrust forward on the shaft this force is transmitted to the hull of the ship through the thrust block which is firmly secured to its foundation; hence its name. By this means all strain is taken off the engine, whose only work is to revolve the shafting which turns the propeller.

As the front side of the collars on the shaft bear against the back side of the webs on the thrust block it is necessary to keep all bearing surfaces well oiled.

Many times the ingenuity of the engineering staff on some of the ships plowing their way through the different oceans, all over the world, has been taxed to the limit when it has been necessary to make temporary repairs in order to reach land. Sometimes the shafting in the tunnel becomes "tired" and a "fracture" develops. This means "splints" and day and night work until it has been so bound up that it will take the strain of "half speed." Sometimes the propeller nut becomes unscrewed and the propeller drops off and is lost. Then come weary hours and much seamanship on the part of the Captain to hold the ship so the engineer can lower and ship the spare propeller. Whole books have been written on such accidents and how to overcome them so no more will be said of them here.

CHAPTER XX

Auxiliary Machinery

Most of the auxiliary machinery is in the Engine Room while two or three pumps are in the Boiler Room. This machinery is necessary to carry on the different functions of pumping water and oil for the different systems described under Piping Systems.

The largest object in the Engine Room beside the main propelling engine is the Main Condenser. The following list of machinery with their descriptions will give a fairly good idea of the work done by them.

Evaporator. All sea-going ships carry fresh water for boiler feed in built-in tanks in the Inner Bottom, but for long voyages the capacity of these tanks is not sufficient to carry all the water needed and an evaporator is carried in the engine room to help out on the water supply. Sea water is run in through this evaporator, heated to a point of evaporation and then distilled. The distilled water is fed to the main condenser.

Evaporator Feed Pump. This pump draws water from the ocean in through a sea valve to the evaporator. It is located in the engine room where it can be easily reached.

Condenser. Every ship carries two condensers, a "Main" and an "Auxiliary." The Main Condenser

is used while the ship is under way and the Auxiliary Condenser is used while at anchor in a harbor.

The steam from the boilers is carried direct through main steam pipes to the engine whether reciprocating or turbine. After the steam has passed through the engine and done its work, it is discharged out from the engine through a large pipe to the condenser.

These condensers are large tanks containing many small tubes through which the exhaust steam passes. During its journey through the tubes it is condensed from the vapor to water, as the outside of these tubes are being kept constantly chilled by sea-water, which is being pumped in from the ocean, forced through the condenser and overboard again.

In the case of the Auxiliary Condenser, the steam from the Auxiliary machinery is carried direct to this condenser rather than the larger one, as the Auxiliary is similar to it and capable of taking care of all the steam used by the Auxiliary machinery; but is not large enough to condense steam from the main Engine.

Main Circulating Pump and Engines. This pump is used to circulate the water through the condenser, drawing it in through the sea chest in the shell plating of the hull, below the water line, sending it through the condenser and out through the overboard discharge pipe above the water line. The pump is generally of a centrifugal design, driven by a vertical simplex engine.

Combined Air and Circulating Pump. This pump is used with the auxiliary condenser. It has the steam in the middle, the water at one end and the air at the other.

This pump draws from the condenser into the Feed and Filter tank.

Air Pump. The air pump is made up of a beam type with two cylinders. When used with the reciprocating engine, the beam works off the low-pressure cylinder cross head.

Another type of air pump which has been used in the past but is not so common at present, has one cylinder, called the "Simplex" but it is more often used for auxiliary purposes.

Feed and Filter Tank. The ordinary form of feed and filter tanks is a receptacle made into four compartments by means of three diaphragm plates, which are open at the top. Water from the air pump is pumped into the end compartment, across the tops of the diaphragm plates into the other end compartment and is then carried off through the lower part of this end of the tank.

In these compartments there are placed "Loofa" sponges, excelsior, or some such material, which catch the grease off the water.

The purpose of this filter tank is to purify the water as much as possible from the grease which has collected during the passage of the steam through the engine, so that when the water has returned as new feed, it will not be greasy water which is run into the boiler.

Feed Water Heater. This heater is used to raise the temperature of the feed water during its passage from the water tanks to the boiler. It consists of a tank containing coils of pipe through which steam is passing. The feed water passes through the tank around the outside

of these coils and is heated by coming in contact with their hot surface.

Fresh Water Pump. This is used for pumping fresh water for drinking and culinary purposes to the different parts of the ship direct or to a Gravity Tank placed on the Boat Deck for this purpose.

Fire and Bilge Pump. This pump is used in case of fire for pumping direct from the ocean through the system of fire hose which carry the water to all parts of the ship. The bilge water is aired through this pump by reverse action and it is possible to pump out any part of the ship's bilges through this pump, the discharge going aboard.

Ballast Pump. This pump is used for moving water ballast from one Inner Bottom compartment to another or for emptying any or all of the compartments, as may be necessary.

Sanitary Pump. This pump is used to force salt water through the sanitary system of the ship, supplying all toilets, deck washing gear, etc.

Lubricating Oil Pump. This pump is used to keep up the constant supply of oil from the lubricating oil tanks to the different bearings of the engine, which require constant lubrication while running.

Oil Cooler Pump. The oil cooler is a receptacle used for passage of lubricating oil while it is being cooled by means of circulating cold water through a portion of the cooler.

Ice Machine Circulating Pump. This pump is used to maintain circulation of air through the condenser of the ice machinery.

Main Feed Pump. This pump is used to draw water from the feed tank to the boiler when the ship is at sea and the main engine running.

Auxiliary Feed Pump. This is similar to the Main Feed Pump and is used, when the ship is in harbor, for the auxiliary machinery. It is run by steam, the same as all the other pumps and is of a duplex type.

Fuel Oil Transfer Pump. This pump is used to force oil from one compartment into another; as the different compartments are emptied and others are to be filled up.

Fuel Oil Service Pump. This is used to pump directly from the Settling Tanks to the Fuel Oil Heater.

Fuel Oil Heater. During its passage through this heater, the oil is raised in temperature until it becomes vaporized and is forced out in the form of gas through the spray nozzles in the boiler.

CHAPTER XXI

Piping Systems

On shipboard it is necessary to convey water, oil and steam for various uses, and for this purpose pipes are employed. Various systems of piping are common to all ships and they differ only in intricacy according to the requirements of the various types of ships. Men-of-war have a most complete and complicated system of piping, while the system aboard transports and other passenger carrying ships is rather less complicated. The ordinary cargo ship (in which we are interested) requires practically a minimum of piping outfit.

The piping lines used for different purposes vary both in kind of material, size, styles of joints, and in other ways. The piping of a ship forms an important item in its construction work, and is carried on in conjunction with the building of the ship structure.

All the systems have forced circulation driven by pumps in the Engine Room controlled by the engineers. Some systems are so connected that if the pump for that system breaks down it can be connected to another pump and function just as well.

In the Boiler Room, against the forward bulkhead there is generally a row of manifolds which control the piping for the fuel oil tanks. In the Engine Room, against the

forward bulkhead, out near the ship's side, there are two rows of manifolds and a third lot in the thrust recess, which control the other piping.

A manifold is a cast-iron fitting with numerous valves in a row. The piping is connected to this manifold and by opening a certain valve and closing all others except one, the oil, water, steam or whatever is being passed, can be sent in an entirely new direction. By opening and closing certain other valves, many different combinations can be made. For instance, if one pump is to operate for a number of pipe lines, they will all lead into a manifold and then any one of them can be connected to the pump by means of the various valves.

Bilge Piping is one of the important systems in all ships. "Bilge" water means any water in the bilges of the ship. It may be clean but more often is dirty. Any water in the Cargo Holds, through rainy weather when they are open or any liquids due to breakage or otherwise which may run out and onto the Tank Top, mingling with the moisture there or any water in the hold due to a leak, in fact anything of a liquid nature is called "Bilge Water."

At the end of each Inner Bottom compartment there is one floor space which is separate from the tank and into which the Bilge Water can drain. These spaces are called "Sumps," "Sump Tanks" or "Wells." They usually run from the Center Line Keelson out to the side of the ship, from the Tank Top to the Bottom Plating, for one floor space.

The bilge pipe starts in one end of these sumps, there being one pipe for each Sump. From the Sumps the

pipes run along the top of the Inner Bottom close to the ship's side, bending out in a loop to clear the brackets of the web frames. The piping runs through the water-tight bulkheads to the manifold in the Engine Room from where it is carried to the Bilge Pump and then overboard or to the Fire Main.

The Bilge Piping in the after end of the ship runs from the Sump Tank up on to the Tank Top and along the Shaft Alley, under the Shaft Stools, on the center line of the ship. The manifold for this piping is in the Thrust Recess at the after end of the Engine Room.

The pipe to the Sump Tanks has a check valve in it just before reaching the tank. The valve can be operated at the valve or on the weather deck, by means of a rod. This is necessary as many times the valve must be operated when the Hold is full of cargo and the valve can not be reached.

The Fire and Bilge Pump is in the Engine Room and is connected to both manifolds at the sides, near forward bulkhead of Engine Room and to the one in the Thrust Recess. This pump will draw from the sea and from the Bilge Manifold, and will discharge to the Fire Main and overboard. (This combination of having one pump for the bilge water and for water for extinguishing fires is common on shipboard.)

Ballast Piping is run through the compartments in the Inner Bottom and is used to convey oil or water to different compartments or to the "Settling Tanks" before the oil goes to the Boiler Room. Ballast Piping must be installed when the ship is being built as the piping

runs through lightening holes in the solid floors and through brackets floors. At the oil- or water-tight floors it is flanged and holes are cut just the size to allow it to pass, the flanges making a tight joint at the floor. As the piping is in long lengths, they must be slipped in through the floor holes when floors are being laid, but the pipes are not connected up until later when the Piping Department is ready to do the work. Ballast Piping obtains its name from the work it does; to carry water ballast or oil, that may be used partly for ballast, from one compartment to another.

From each compartment there is a pipe leading to the manifold near the forward bulkhead of the Boiler Room and from there it is carried to the Ballast Pump in the Engine Room.

Both the Fore and After Peaks are pumped empty through the Ballast Piping. Pipes are carried to the manifold the same as for any of the compartments.

The Ballast Pump will draw from the sea, from the Ballast Main and from the Bilge Main and will discharge to the Settling Tanks, overboard or to the Fire Main. (This combination of drawing also from the Bilge and Fire Mains is a common arrangement as this pump can then be used in case of any trouble with the other.)

Fire System. This piping is independent of all others as it is designed to be used in an emergency and must always be ready for such use; hence it must not be used in connection with any other work so that, by chance, it might be in use at a time when it was needed to extinguish a fire.

This piping runs direct from the pump up through the Engine Hatch and branches out on the weather decks with leads running both forward and aft. There are outlets placed at advantageous points where canvas hose can be attached and it is generally so arranged that these are near enough so that any two hose can play on the same part of the ship. In other words, so that if there is trouble with one hose the other one can do the work.

The outlets are brass couplings fitted with a valve and the canvas hose is stowed within easy reach of the coupling so it can be ready for immediate use.

One lead of iron piping runs direct from the pump to the Fore Peak Tank and another lead runs to the After Peak Tank. These tanks are filled by this system (and emptied by the Ballast Piping).

As explained under Bilge Piping the pump which does the work for this system also acts for the Fire System as these two systems would not be working at the same time or if the Bilge System were in use it could be quickly turned over into the Fire Main.

This pump is always known as the Fire and Bilge Pump and will pump the ship free of Bilge Water, or water due to a leak in the hull or pump water in from the sea and throw it onto a fire.

There is another system of piping which is not, strictly speaking, part of the "Fire Main," but is used for the same purpose. This is a series of pipes carried from the Engine Room to different parts of the Cargo Holds with open ends on the pipes. Whenever there is a fire in the cargo the hatch covers can be left on the hatches and steam

sent into the hold in which the fire is burning. The steam fills the air and smothers the fire. These pipes are called "Smothering Pipes" for this reason.

Sanitary Piping. This is used for carrying sea water for "housekeeping" purposes. The water direct from the sea is used in flushing water closets, washing down Galley floor, decks, and any purpose where water would be used that need not be fresh water. (Fresh water is carefully kept and used on board ship for cooking, drinking and bathing.) The piping is also carried to the "Oil Coolers" in the Boiler Room where it acts as a cooling agent in the water jacket around the oil.

The Sanitary Pump will draw from the sea and discharge to the Sanitary System, Water Service and Oil Coolers.

Main Steam Piping is the large diameter, heavy piping from the boilers to the main propelling engine, whether reciprocating or turbine. The branches from the boilers are run to one common pipe in the Boiler Room and through the bulkhead to the engine. Valves in the branches make each boiler independent of the others. The main steam valve shutting off the flow of steam through the pipe to the engine. Leads of these pipes vary with the arrangement of the Boiler and Engine Rooms so no attempt will be made to describe the layout of piping.

Auxiliary Steam Piping is the multitude of small pipes which serve the auxiliary machinery. Each system of piping takes its name from the pump which it serves. To an experienced workman installation of the piping in the Engine Room of a ship is an arduous job and to one who

works on it for the first time it is very baffling and difficult to understand. After the piping is out of the Engine Room and on its way to the end of the line the work is more simple.

The arrangement of this piping is laid out in the Drafting Room of the Engine Department and is closely followed by the workmen on the job. In the Navy the piping is painted certain standardized combinations of color on the joints so that men who are working the ship and were not on board when it was installed will be able to trace the pipes through the ship when making any repairs or alterations.

The principal piping for the auxiliaries are the following:

Fire and Bilge Pump
Ballast Pump
Sanitary Pump
Fresh Water Pump
Evaporator Feed Pump
Ice Machine Condenser Circulating Pump
Combined Air and Circulating Pump
Main Circulating Pump (and engine)
Main Feed Pump
Air Pump
Auxiliary Feed Pump
Lubricating Oil Pump
Oil Cooler Pump
Fuel Oil Transfer Pump (In Boiler Room)
Fuel Oil Service Pump (In Boiler Room)
Main Surface Condenser

Auxiliary Surface Condenser
Evaporator
Feed and Filter Tank
Feed Water Heater.

As all of these systems of piping are in the Engine Room, except those noted as being in the Boiler Room, and some Engine Rooms are about twenty-five feet long and fifty-five wide, there would seem to be considerable piping in a small space.

Among the auxiliary machinery there is an important system not yet mentioned; it is the "Steam and Exhaust" for the "deck machinery." This includes the Steam Windlass on the Forecastle Deck, the Capstan on the Poop Deck, the Steering Engine under the Poop Deck and all the Cargo Winches at the hatches, for handling the Cargo Booms. All of this piping is well insulated to protect it in cold weather. Steam piping for the signal whistle and siren at the funnel is a separate lead of small sized pipe.

Fresh Water Piping. This system draws from the Fresh Water Tanks and from the Reserve Feed Tanks.

The Fresh Water Tanks are generally located in one corner of the Engine Room. They are two, large, square tanks of steel plate, well riveted and caulked tight. They have swash plates to prevent undue motion of the water when the ship is rolling in a seaway and which also help tie the sides of the tank together, to prevent bulging of the flat surfaces. These tanks are placed on strong foundations and are well secured, to hold them in place.

The Reserve Feed Tanks are those compartments in

the Inner Bottom, usually directly under the Engine Room, which are used for storing fresh water. This water is used for feed water to the boilers as needed. It is generally as clean as the water in the tanks in the Engine Room. To prevent rust from the plating getting into the water the inside of these tanks is coated with neat Portland Cement. In order that the daily service of fresh water need not depend on a pump pressure, a Gravity Tank is installed on the highest deck, water is pumped directly there from the water tank in the engine room and the water is supplied from the Gravity Tank to the different faucets in Living Quarters and Cook's Galley. For drinking water for the crew a "Scuttle-butt" is generally placed on the Upper Deck and is connected to the Fresh Water System. It is a small tank set up on a stand, with cups for drinking.

All fresh water discharge, that water which has been used, drains overboard through a scupper in the ship's side.

Steam Heating System. All Living Quarters, as mess rooms, state rooms, wheel house, washrooms, etc., are heated by steam, as the ships must be comfortable during the extreme winter weather on the North Atlantic Ocean.

The radiators are made up of "coils," usually 1 in. brass pipes with return bends so they are flat and can be hung on the bulkheads, to save space.

The Cook's Galley has a steam-heated table for keeping food warm, steam coil in the bottom of the sink for heating dish water and urns for heating water for coffee, etc. The baths and showers have a steam heater; a large pipe

which contains steam and through which the water pipe is passed, the water becoming heated while in transit.

All steam supply and return pipes are well insulated. The drain pipes from the heaters are all trapped and return to the drain tank in the engine room.

One of the important leads of piping is the steam coils in the Inner Bottom. The cold water which a vessel passes through during voyages in the North Atlantic in the Winter chills the hull to such an extent, below the water line, that the fuel oil in the Inner Bottom will become thick and refuse to flow readily through the feed pipes to the Settling Tank, preparatory for use in the boilers of an oil burning steamer. It is necessary to have means for keeping this oil sufficiently warm to flow. Radiator coils are fitted in the end of each tank, near the suction pipe for the oil, and are supplied with steam the same as any radiator in the Living Quarters. They are drained by an extra pipe. By means of these coils the temperature of the oil can be governed so that it is available at all times.

CHAPTER XXII

Hull Engineering

Steering Gear

Steering of the ship is usually done by a small hand wheel located in the Wheel House on the Bridge. Often a second wheel is fitted on top of the Wheel House, vertically over the other, and is connected to it by a rod which can be disconnected within a few minutes if so desired.

Directly attached to the head of the rudder post there is a yoke with two arms, standing at right angles with the keel. At the outer end of these arms connecting rods run forward to a sleeve which travels fore and aft according to the rotation of the threaded shaft on which the sleeve rides. The arm on the yoke, connecting rod and sleeve are in two sets which are built side by side.

The forward end of the threaded shaft is turned by means of a gear wheel. This gear wheel interlocks and can be turned by a combination of gears which lead from a small, steam "steering engine," or can be operated by a double hand wheel which can be handled by four men.

The steering engine can be operated by either of the steering wheels, on or in the Wheel House and by a small wheel close by the engine. All of the steering gear machinery is located on the deck just forward of the rudder stock, and is enclosed by a light, steel bulkhead.

The small steering wheel and the double hand wheel, aft, are for an emergency in case the forward wheels break down. Should the steering engine itself be in trouble the ship could still be managed as a Spare Tiller is fitted on top of the Rudder Stock, above the yoke. In the end there are two eyes for attaching two sets of rope tackle. By removing the pins which hold the connecting rods to the arms of the yoke and swinging the rods out of the way, the steering tackle being hooked into pad eyes on the ship's side (put there for the purpose), it is possible to steer the ship until she reaches port or until the necessary repairs have been made on the steering engine.

Communication between the forward steering wheels and the steering engine is maintained by two pipes which lead from the base (or standard) of the wheel in the Wheel House, down, under the decks and aft to the steering engine. These two pipes are filled with a solution, often glycerine and water, under pressure, and by turning the forward wheel, plungers in the standard are moved and, by increased pressure in one pipe and decreased pressure in the other, corresponding plungers in the steering engine are affected and when these move they operate the slide valve in the steam chest and the steering engine acts to turn the combination of gears and thus swing the rudder to port or starboard.

Ventilation

Ventilation in battleships and large passenger steamers is quite a problem, but for the type of cargo steamer which is being described the ventilation is a simple matter.

All the living quarters are above the main weather deck except the engine and boiler rooms, and receive all necessary ventilation through doors and air ports.

The Engine Room often has four cowl ventilators fitted, one in each corner of the Engine Hatch, standing above the skylight enough to have an unobstructed draft.

The Boiler Room is fitted with two cowl ventilators, of larger diameter than those in the Engine Room. They are fitted in the two forward corners of the boiler hatch and stand above the Fidley Hatch high enough to have a good draft. The cowl hood of all these ventilators is built separate from the ventilation trunk pipe (which is round in section) and rests on top of the trunk as a guide, so the cowl can revolve. On the outside of the cowl, below the throat and just above the trunk a gear rack is fitted to engage with a pinion gear wheel. The handle to operate the wheel is below in the Engine or Boiler Room, directly under each ventilator trunk so the men in the rooms below are able to turn the cowl up on deck until it catches the direction of the wind and gives a good down draft to the rooms below.

The ventilators in the Boiler Room are made larger in diameter as they are also used as elevator shafts. The Boiler Room has ash buckets which are used to raise and dump ashes over the side into the dump scows while in harbor, if the steamer is a coal burner. Oil-burning ships are also often provided with these buckets.

This bucket is hoisted by a rope over a drum in the ventilator trunk which is turned by a crank on the outside of the trunk. Light angle bars are used as guides

to keep the bucket in center of the trunk. A door is in the side of the trunk just above the weather deck, with top of the door a little below the rope drum. The turning gear for the cowls is independent of the elevator and the cowls can be operated in the same way as those over the Engine Room.

The ventilation trunks are built down until they stop a little above a man's head. In this way all the down draft is carried to the Engine and Boiler Room floors where it is needed.

The top of the Engine Room Casing ends in a skylight, built with a number of small shutters, hinged at one end, with a bar to hold the other end open at varying heights. These shutters have glass ports to admit light. The shutters can be opened and closed by a gear operated from below. When an exhaust is wanted to draw out the hot air, the skylight shutters are opened according to the wind; with fresh air pouring down through the ventilator trunk from the cowl, a fine draft is created. The top of the hatch on the Boiler Room is called the "Fidley" and it is cut out for the funnel and the two ventilator trunks to pass through.

In addition, some Fidleys have rectangular openings as large as possible, the size being limited by the framing of the hatch. To prevent accidents, these openings are protected by gratings of round iron bars and having no fixed covering, they can be covered with tarpaulin (canvas) during stormy weather, if so desired. These openings serve the same purpose as the skylight shutters over the Engine Room, being an opening for the exhaust for hot air.

Electric Lighting

The ordinary layout for the electrical installation places two marine type generating sets, direct connected to a small steam turbine on the "Dynamo Flat." This is usually a small platform built half way up, on one side of the Engine Room, where it is easily accessible and out of the way.

Practically all that is required of this outfit is to illuminate the ship as all power is steam driven. The slate switch board is located in the Engine Room where it can be attended by the Engineers.

The "Side Lights" (port and starboard), Stern and Anchor Lights are built to use either electric or oil lamps but the Range and Masthead Lights are electric only.

All Living Quarters as Mess Rooms, State Rooms, Galley, etc., Engine and Boiler Rooms, Shaft Alley, Paint Room and Store Rooms are lighted by incandescent lamps. The weather decks are lighted by means of single lamps attached to the outside of the deck houses.

Work about the ship and in the Cargo Holds is done with "Cluster Lights," there being a number of lamps attached to a single holder and protected by a large reflector which throws all the light in the direction desired. These "clusters" are on long, portable electric cables so they can be placed where work is going on. The generators are designed to stand a sudden change from no load to full load and vice versa, so it is not necessary to ever think of them when using the electric current.

CHAPTER XXIII

Engine Dock Trial

After the boilers and main steam line have been tested out by applying the required hydrostatic pressure, the water is blown out; if the boilers are of the Scotch type, the local inspectors enter the boiler to see if any distortion has taken place while the pressure was applied.

If the boiler is of the water tube type, the water is blown down below the steam drum, and the Inspector makes an inspection of the steam drum only. The boiler is then closed up and the water pumped up till it shows about 3 ins. in the glass. The fire bars are then primed with a layer of lumpy coal, about 3 to 5 ins. thick, and the necessary wood thrown on top to ignite the coal.

If the Donkey Boiler, or any other boiler on the vessel, is under steam, some hot coal can be taken from the furnace, instead of using wood, to ignite the green coal.

The air cock, which is provided on top of the boiler, and the gauge cocks, which are at about the water level, should be opened, so that as the water expands and steam is formed, any air in the boiler will be forced out.

Scotch boilers are usually equipped with hydrokemeters, or if the piping is so arranged the water can be circulated by taking it out of the bottom blow connection, and returning it to the boiler through the feed line. As

soon as fires are started the auxiliary feed pump, which is usually connected for the circulation, should be started. This can be done by connecting the air hose and breaking the exhaust line, and the pump can run until there are 30 or 40 lbs. of steam on the boiler.

When steam is formed so that it can be observed escaping from the air cock, the small gauge cocks which were left open should then be closed and the steam allowed to rise gradually to the required pressure for "cutting in."

If the boiler is of the water tube type, it is not necessary to circulate the water, and hydrokemeters, or other methods of circulation, are never used.

On boilers of the Scotch type, provided with some method for circulating water, steam can safely be raised in from three to five hours. On the boilers of the water tube type this can be done in much less time—say from an hour to an hour and a half, if there is a proper method for forcing the fire.

In new vessels, where steam is being raised for the first time, it is best to "cut in" the boiler; that is: open up the top valves to the auxiliary machinery when the steam has reached sufficient pressure to work the auxiliary machinery, which would be around 75 to 100 lbs.

In cutting in the steam line, the valve should be only "cracked" off the seat, and the steam allowed to rise in the steam lines gradually, as a sudden opening of the valves would tend to lift the water from the boiler, when it would pass over the steam lines into the auxiliary machinery.

When auxiliary machinery is run for the first time (and this is also true of dock trials) the condensed water should not be allowed to return to the boilers, as in manufacturing (in assembling the piping) a great deal of oil and grease is used. By letting this water run into the bilge, the accumulated oil would not return to the boilers and cause injury. This is generally done by breaking the discharge pipe from the main and auxiliary air pumps, thus letting the water flow to the bilge and "make-up" feed for the boilers is taken from the shore lines.

After all of the different pumps (dynamos, steering engine, winches, and other auxiliary machinery) have been tried out under steam, and it is found that they function satisfactorily, the vessel is then ready for dock trial.

Before the propeller is turned over, it should be seen that sufficient lines are out fore and aft, and also "breast" lines, so that the engines can be worked in both the ahead and stern motion, without moving the ship more than a small distance from her position at the dock. When the word is given to get under way, the first precaution to be taken is to give the engines a complete revolution with the jacking engine, and the engineer noting that there is none of the oil piping, or other parts that foul anything. Then the jacking engine gears should be taken out and secured; the main sea valve injection should be opened, the overboard discharge valve opened and the main circulating pump started up.

Air cocks are usually provided under the condenser heads to let out the air, so that water will pass through all

of the tubes, which would be pocketed if there were not an air vamp.

After it is found that the main circulating pump is functioning properly and the main and auxiliary feed pumps will deliver water, the main stop valve should be cracked on the engine, allowing steam to pass up to the throttle valve. If there is a drain on the main steam line this should be opened so that whatever condensed water is standing in the pipes may drain off and make sure that nothing but dry steam reaches the engine.

The reversing engine should be worked a few times in both directions, if the engine is of the reciprocating type, and then crack the by-pass valve to the high, intermediate and low cylinders, if it is of the triple expansion type, leaving all drains open.

The reversing engine should be worked at intervals (every minute or two) so that the steam passing into the valve chest and on into the cylinders, will have ample chance to reach both sides of the piston, and have all parts of the cylinders warmed up. After the engines have been warmed sufficiently, the throttle valve should be cracked and the engines allowed to make a half turn, and then brought into the reverse motion with reversing engine, or (what is commonly termed by engineers) the engine should be "rocked." After this has been done for several minutes, the engine should be then allowed to make a few revolutions in the ahead motion and all bearings and other parts watched so that they should not be warming up or becoming overheated. The number of revolutions of the engine should gradually be increased until the engine

is developing the proper horsepower, and should be run at this speed for from two to three hours. If any of the bearings become overheated, or any adjustments are necessary, the engine should be stopped and the proper adjustments made.

In order to run a satisfactory Dock Trial, it sometimes is necessary to run for a short time and stop the engines and make the necessary adjustments for whatever trouble may develop.

When the engines have been run sufficiently to determine their condition and all is found to be satisfactory, the steam is allowed to fall and the engineers turn their attention to "slicking up" their quarters. From now on until the time arrives when the ship is fully equipped and ready for sea the Engine Room Force is becoming accustomed to the ship and all layout of piping, etc.

The progress of this ship has been traced from the time the first keel plate was laid, through the construction of the hull, the launching and fitting out of the propelling machinery and other equipment.

The description has been brief in many parts, of necessity, due to space allowed in this little book. For more detailed description of the engines and boilers the reader is referred to the technical books which are written exclusively on those subjects. The problems of design which are met in the Drafting Rooms of the shipbuilding company that is building this boat, have not been referred to at all, as that is not the purpose of this volume. For such information one should obtain a book giving the work in "Theoretical Naval Architecture," as this description has been written with a view of showing the average shipyard worker some of the things which are going on around him and with which he may be unfamiliar. If it has been of any such help the writer will feel well rewarded for the evenings spent in preparing these pages.

As a last word, don't forget SAFETY FIRST, for yourself and for your fellow workers, for your family and for theirs.

Never look aloft while walking on deck or staging. If it is necessary to look upward, stand still while doing so.

Never place wrenches or other tools where they may fall—think of the men below you.

"Eternal Vigilance is the Price of Safety."

SHIP NOMENCLATURE

A

Access Hole. An entrance to a compartment.

Accommodation Ladder. A ladder or stairway which can be suspended from ship's side to permit a person or persons to board a ship from a small boat.

Aft. Position between amidships and stern of ship.

Aft End. Position at or near stern of ship.

After Peak. Aftermost tank or compartment of a ship, used for trimming the ship.

After Peak Bulkhead. Last water-tight bulkhead of a ship.

After Perpendicular. A vertical straight line at the after edge of the rudder post.

Air Hammer. Hammer driven by compressed air for riveting. Sometimes called an air gun or "gun."

Air Holding-on Hammer. Hammer with air cushion for holding against a rivet.

Air Port. A circular opening in the ship's side.

Amidship. Section of a ship half way between bow and stern.

Anchor. A heavy steel device that is attached to the end of a large chain or hawser to be dropped to the bottom for holding the ship in position when not alongside a dock.

Angle Collar. Flange made of angle iron.

Anneal. To heat and cool metal for the purpose of softening.

Apron Plate. A bulwark plate at stem head, extending aft a short distance for housing "bow chocks" also to assist in keeping the forecastle dry.

Assemble. To fit two or more parts together, forming a section of a larger part.

Athwartships. Across the ship, at right angles to the keel.

Auxiliaries. Various winches, pumps, motors, and other small engines required on a ship.

Auxiliary Foundations. Supports for pumps, distillers, condensers, etc.

Awning Deck. Shelter or bridge deck.

B

Backing Angle. An angle fitted on the back side of another angle to reinforce same.

Ballast. Substance carried by a ship to insure stability.

Ballast Tank. Water-tight compartment to carry water ballast.

Batten. A thin strip of wood used in measuring or making templates. (See also Cargo Batten.)

Beam. An athwartship member supporting a portion of a deck. Also the width of the ship.

Beam Bracket. Plate at ends of beam, riveted to beam and frame.

Beam Knee. Bracket made by splitting and bending the end of an I-beam or channel to form a knee brace.

Below. Below a deck or decks (corresponding to "downstairs").

Bending Floor. Large iron floor on which frames are bent.

Bending Rolls. Large machine used to give curvature to plates.

Bending Slab. Heavy cast-iron blocks arranged to form a large solid floor on which angles are bent.

Berth. A place for a ship; sleeping accommodations.

Bevel. The angle between the flanges of a frame and other member. (When greater than a right angle, "open bevel"; when less, "closed"). To change the angle of an angle bar to make it fit in a certain place.

Bevel-faced Holding-on Hammer. A heavy hammer with sloping face for holding against a rivet.

Bilge. The rounded portion of the hull between the side and bottom.

Bilge Keel. A fore-and-aft plate fitted to the outside of the shell plating running along the bilge, used to prevent excessive rolling of the ship.

Bilge Pump. Pump for removing waste water from bilge of ship.

Bilge Strake. Longitudinal course of shell plates between bottom and sides of ship.

Bilge Water. Water which accumulates in the bilge of a ship.

Bitts or Bollards. Heavy steel castings fitted to the weather deck for securing mooring lines or hawsers.

Bitumastic. An elastic cement covering for inside of compartment, decks, etc., to prevent material from rusting and prolonging life of same.

Boiler Saddles. Supports for boilers (foundations).

Booby Hatch. Water-tight covering over an opening on deck for a stairway or ladder.

Boom. A long round heavy spar, pivoted at one end, generally used for hoisting cargoes, etc.

Boom Crutch. Support for booms when same are not in use.

Bosom Piece. A short angle connecting the ends of two angles.

Boss Plate. Plate bent to fit around the boss in stern casting at the propeller shaft.

Bottom. Portion of the hull below the bilge.

Bounding Bar. Angle iron fitted around the edge of a plate or plates of bulkhead or deck to make a water-tight connection.

Bow. The forward end of a ship.

Bracket. A small plate used to connect two or more parts, such as deck beam to frame, frame to margin plate, etc.

Breast Hook. A plate structure fitted inside the hull near the bow to give local strength to the shell plating.

Bridge. The athwartship platform above the weather deck from which the ship is steered, navigated, etc.

Bridge Deck. Partial deck extending from side to side of ship, located about amidship.

Bridge, Long. Built-up span connecting forward deck houses with after deck house.

Building Slip. Place where the ship is built, before launching.

Bulb Angle. An angle with one edge rounded.

Bulb Plate. Plate reinforced at one edge.

Bulb Toe. Bar reinforced at toe of standing flange.

Bulkhead. A vertical partition corresponding to the wall of a building, extending either athwartships or fore-and-aft, and separating one compartment from the other.

Bulkhead Sluice. A small opening cut down to top of the bulkhead angle connecting to tank top; fitted with valve, and worked with a rod from any deck above.

Bull Riveting. Riveting with a compressed air or hydraulic plunger riveter.

Bulwark. Shell plating extending above the top deck of a ship.

Bunker. A compartment used for the stowage of coal or other fuel.

Buoyancy. Ability to float, or the difference between the weight of the ship and the upward force of the water that it may displace.

Butt Joint. A joint formed by "butting" the edges of plates together.

Butt Strap. A small plate or other member used to connect the two parts of a butt by overlapping each.

C

Camber. The athwartship curvature of a deck. Sometimes called "round up."

Cant Frame. A frame not square to the keel line (small frame supporting overhang of stern).

Capstan. A revolving device, with axis vertical, used for heaving in lines.

Cargo. The freight carried by a ship.

Cargo Batten. Strips of planking on the inside of the frames in the hold to keep cargo away from shell of ship.

Cargo Boom. Heavy boom used in loading cargo.

Cargo Hatch. Large opening in a deck to permit loading of cargo.

Carling. Fore-and-aft member at side of hatch, extending across ends of beams where cut to form hatch.

Casing. Trunk enclosing portion of a vessel.

Caulk. To make water-tight or oil-tight.

Caulker. A man who makes seams tight in wood or metal. Caulker usually means a metal caulker. If wood caulker is meant the term "wood caulker" is used.

Ceiling. Wood or steel sheathing on inner bottom frame brackets to protect cargo.

Center Line. The middle line of the ship, from stem to stern.

Chain. Usually refers to heavy chain attached to anchor.

Chain Locker. Compartment in forward lower portion of ship in which anchor chain is stowed.

Chain Pipe. Pipe for passage of anchor chain from deck of ship to chain locker.

Chart House. Small room under bridge used for charts and navigation instruments.

Chock. Cradle or support to prevent objects from shifting, usually of wood. A heavy fitting through which ropes or hawsers may be led.

Chock, Bower. An extra large chock, fitted well fordward for use of Bower anchor.

Chock, Roller. One with a shieve or shieves to prevent chafing of lines.

Cleat. A fitting attached to the deck, having two fore-and-aft arms or projections around which a rope or line may be secured.

Clip. A short angle bar.

Coaming. The vertical plates of a hatch or skylight, which extend above the deck.

Cofferdam. The space between two bulkheads located very close together.

Collar. A flanged band or ring.

Collision Bulkhead. First water-tight bulkhead from bow of ship.

Compartment. A subdivision of space or room in a ship.

Counter. Overhang at stern of ship.

Counterplates. Shell plates around the stern at the upper or weather deck.

Countersink. The taper of a rivet hole for a flush rivet.

Cowl. Hood-shaped top of ventilator pipe.

D

Davit. Heavy vertical pillar, of which the upper end is bent to a curve, used to support the end of a boat when hoisting or lowering.

Dead Flat. The flat part of the amidship side or bottom of a ship.

Dead Rise. The rise or upward slant of the bottom of a ship from the keel to the bilge.

Deadweight. The total weight of cargo, fuel, water, stores, passengers and crew, and their effects, that a ship can carry.

Deck. The part of a ship that corresponds to the floor of a building.

Deck (Awning). Shelter deck.

Deck (Boat). One on which life boats are carried.

Deck (Bridge). Partial deck extending from side to side of ship, about amidships.

Deck (Forecastle). Partial deck at bow of ship, raised above upper deck.

Deck (Girder). Strength member extending either fore-and-aft or athwartships to support deck.

Deck (House). Shelter built on exposed weather deck.

Deck (Hurricane). Or boat deck.

Deck (Lower or first). First full deck above tank top or bottom.

Deck (Main or second). Second full deck above tank top or bottom.

Deck (Poop). Partial deck at stern of ship, raised above upper deck.

Deck (Promenade). Set aside for use of first-class passengers on passenger ship.

Deck (Upper or third). Third full deck above tank top or bottom.

Deck (Orlop) Partial or balcony deck between tank top and lower deck.

Deck Stringer. The strake of plating that runs along the outer edge of a deck.

Derrick. A device for hoisting heavy weights, cargo, etc.

Development. Expanded to full size.

Die. A tool for forming a rivet head (applied to rivet dies).
(*a*) Flush die—to flatten rivets into a countersunk hole.
(*b*) Snap die—to form a round head.

Displacement. The total weight of the ship when afloat, including everything on board; the volume of water displaced by a ship.

Docking Keel. A keel fitted on both sides of a large ship, bottom of each on a level with outside of flat keel, used to distribute the weight of a ship when in dry dock.

Dog. A small, bent metal fitting used to close doors, hatch covers, manhole covers, etc.

Dolly bar. A heavy bar to hold against a rivet.

Double Bottom. Compartments at bottom of ship between inner and outer bottoms, used for ballast tanks, water, fuel, oil, etc.

Doubling Plate. A plate fitted outside or inside of another to give extra strength or stiffness.

Draft. The vertical distance of the lowest part of the ship below the surface of the water when she is afloat.

Drag. The amount that one end of the keel is below the other when the ship is afloat, but not on an even keel.

Drift Pin. A small tapered tool used to draw adjoining parts together, so that the corresponding rivet holes will come in line.

E

Entrance. The forward part of the hull at the water line.

Erection. The process of hoisting into place and bolting up the various parts of the ship's hull, machinery, etc.

Even Keel. A ship is said to be on even keel when the keel is level, or parallel to the surface of the water.

Expansion Trunk. A built-up trunk extending fore-and-aft, over a series of oil compartments, of sufficient capacity to admit the expansion of oil due to changes of temperature.

Eye Bolt. A bolt formed with an eye or ring at one end.

F

Fabricate. To punch, cut, sheer, drill, bend, flange, or weld plates and shapes.

Fair. Smooth without abruptness or unevenness, in agreement. Fairing the lines consists in making them smooth. Rivet holes are fair when they agree one with another in adjoining members.

Fairlead. A small fitting through which a rope, or chain may be led so as to change its direction without excessive friction.

Fan Tail. Overhanging, round stern of ship.

Faying Side. The side of a punched plate from which the punch enters.

Faying Surface. The surface between two adjoining parts.

Fender. A fitting or device to prevent damage to a ship's hull at or near the waterline by other vessels, floating objects, docks, etc.

Fidley Hatch. Hatch around smokestacks and uptake.

Fine Lines. When ship is sharp pointed at the ends.

Flagstaff. Flag pole at stern of ship.

Flange. Portion of a plate or shape at, or nearly at, right angles to main portion.

Flare. Curvature of the forward frames outward.

Flat. A small, partial deck, built level, without curvature.

Floor. The lower portion of a transverse frame, usually a vertical plate extending from center line to bilge, and from inner to outer bottom.

Flush Rivet. A rivet driven with a flush die. (Has a point even with plate or nearly so.)

Fore-and-aft. In line with the length of the ship, longitudinally.

Forecastle. The forward, upper portion of the hull, generally used for the crew's quarters.

Fore Peak. A large compartment or tank just aft of the bow in the lower part of the ship, used for trimming ship.

Forefoot. Bottom of the curve of the stem.

Forging. A mass of steel worked to a special shape by hammering while red hot.

Forward. Near or toward the bow.

Foundations. Supports for engines, boilers, etc.

Frame Mold. Template for the frame of a ship.

Frame, Side. Inside frames of a ship connecting to shell plating.

Frame Spacing. The fore-and-aft distance between adjacent frames.

Frames. Upright members or ribs forming the skeleton of a ship.

Frames, Continuous. Frames combining side frames and floors, extending continuous through decks.

Frames, Reverse. An angle fitted on the back side of the original frame to reinforce same.

Frames, Web. Heavy built-up frame of angle iron and plates.

Framing. The support and stiffening of the shell plating, deck plating. Usually consists of the ordinary transverse frames (or "ribs") beams, floors, and the longitudinal framing, as keel, keelsons, longitudinals and stringers.

Freeboard. The vertical distance from the upper watertight deck or top of bulwarks to waterline, when ship is fully loaded.

Freeing Port. Holes through bulwarks of ship to discharge water from deck in case of shipping a sea.

Full Lines. When ship is blunt pointed at the ends.

Funnel. Smokestack of a ship.

G

Galley. Cook room or kitchen of a ship.

Galley Dresser. A cook's work table.

Galvanizing. Coating metal parts with zinc for protection from rust.

Gangway. A passageway, a ladder or other means of boarding a ship.

Garboard Strake. The strake of shell plating next to the keel.

Girder. Strength member used as a support.

Girth. The transverse distance around a ship.

Gravity Tank. One elevated so that contents will flow to desired places without use of pressure.

Gross Tonnage. A figure obtained by dividing the total volume of the ship, in cubic feet, by 100.

Ground Ways. Timbers fixed to the ground, under the hull on each side of the keel, on which she is launched.

Gudgeons. Bosses on stern post drilled for pins, on which rudder swings.

Gunwale. The side of a ship above the weather decks.

H

Harpin. A curved wooden piece used to hold frames at ends of ship in position when first erected.

Hatch. Opening in deck, for passage of people or cargo.

Hatch Beam. Portable beam across a large hatch for supporting covers.

Hawse Pipe. Casting extending through deck and side of ship for passage of anchor chain.

Hawser. A large rope.

Hawser Hole. Hole through bulwark for passage of a rope.

Heater or Heater Boy. One who heats rivets.

Heating Tongs. Tongs used to take a rivet from the fire.

Heeling. The degree of inclination of a vessel from the perpendicular.

Helm. The direction to which the tiller is put, or opposite to which the rudder is put. (When the rudder is to port the ship is said to carry starboard helm.)

Hogging. Straining of the ship that tends to make the bow and stern lower than the middle portion.

Hold. That part of a vessel where cargo is carried.

Hold Beams. Beams in a hold, similar to deck beams, but having no plating or planking on them.

Hook Stick. A rig used to hold drilling machine for light drilling.

Horn. To line or square up.

Hull. The body of a ship, including shell plating and frames.

I

Inboard. Inside the ship, toward the center line.

Inner Bottom. Plating forming the upper boundary of the double bottom. Also called "tank top."

Inserted Packing. Canvas strips soaked with red lead fitted between connections that cannot be caulked successfully, to insure a tight job.

Intercostal. Made in separate parts between frames, beams, etc., the opposite of continuous. (Floors are continuous; longitudinals intercostal, in a merchant ship.)

Isherwood System. System of framing a ship chiefly with longitudinal members.

J

Jackstaff. Flag pole at bow of ship.

Jam Hammer. A special type of holding-on hammer used in heavy riveting.

Joggling. Offsetting the edges of plates of outer strakes to avoid the use of "liners."

K

Keel. The fore-and-aft member, usually in the form of flat plates end to end, extending from stem or stern along the bottom of a ship on the center line.

Keel, Bilge, or "Rolling Chock." Narrow plate and angles, fitted to reduce rolling motion of ship.

Keel Blocks. Heavy blocks on which ship rests during construction.

Keel, Vertical (Keelson). One made up of vertical plates extending fore-and-aft, located on the center line of flat keel.

Keelson, Side. Fore-and-aft member located on each side of center keelson.

King Post. Vertical post to support cargo booms.

Knuckle. A sharp bend in a plate or bar.

Knuckle Plate. One with a sharp bend.

L

Ladder. Inclined steps, aboard ship taking the place of "stairs."

Landing Boards. Boards on deck beside hatches, for landing cargo when loading.

Lap. A joint in which one part overlaps the other, thus avoiding the use of a butt strap.

Launching. The operation of placing the hull in the water by having it slide down the launching ways. During launching the weight of the hull is borne by the "sliding ways," which are attached to the hull and slide with it down the "ground ways."

Laying off. Marking plates, shapes, etc., for shearing and punching from template.

Length between Perpendiculars. The distance from the fore part of the stem to the after part of the stern post on a line of the upper deck.

Length over All. The length of a ship measured from the stem to the aftermost point of the stern.

Lift. To lift a template is to make it from measurement given and also to suit conditions.

Lightening Holes. Holes cut in plates and frames to reduce weight.

Limber Hole. A hole of a few inches diameter cut in a floor plate near the bottom to allow water to drain through it.

Liner. Generally a small tapered plate fitted between plates at a lap, sometimes of parallel thickness for outside plates.

Lines. The plans of a ship that show its form. From the lines, drawn full size on the mold loft floor, are made templates of the various parts of the hull.

Loftsman. A man who lays out and makes molds for a ship.

Longitudinal. A fore-and-aft vertical member running parallel, or nearly parallel, to the center vertical keel through the double bottom. In merchant ships longitudinals are intercostal.

Lugpad. A projection on deck with hole for fastening a block for a lead.

M

Main Deck. The principal deck of the main hull.

Manhole. A round or elliptical shaped hole cut in a bulkhead or tank top. Large enough for a man to pass through.

Margin Bracket. One connecting side shell to margin plate of inner bottom.

Margin Plate. Outboard strake of inner bottom plating connected to shell.

Marker. Brass pipe dipped in paint for marking rivet holes.

Mast. A large round piece of timber or iron tube standing nearly vertical, at the center line of ship on the deck.

Mess Room. Dining room for officers and crew of a ship.

Midship. At the middle of the ship's length.

Midship Section. A plan showing a cross-section of the ship amidships. This plan shows sizes of frames, beams, brackets and thickness of plating.

Mooring. The act of securing a vessel to a particular place.

Mold. A light pattern of a part of a ship. Usually made of thin wood or paper. Also called a template, for laying out plates or shapes.

Mold Loft. A shed or building with large, smooth floor on which the lines of a ship can be drawn to full scale and templates lifted.

N

Net Tonnage. A figure obtained by making deduction from the gross tonnage to allow for space not available for carrying cargo.

O

Oakum. Material used for caulking seams of wood deck.

Oil Tight. Riveted and caulked to prevent oil leakage. (Rivets must be more closely spaced for this purpose than for watertightness.)

Old Man. A rig for holding a drill.

On Board. On or in the ship.

On Deck. On the upper deck, in the open air.

Outboard. Direction out from center line of ship toward either side.

Overall Length. Length beyond the distance between perpendiculars. (Total length.)

Overboard. Outside, over the side of a ship. Into the water.

Overhang. Portion of the hull over, and unsupported by, the water.

Oxter Plate. Bent shell plate which fits around the upper part of the stern post. Sometimes called, "tuck" plate.

P

Packing. Material put between plates or shapes to make them watertight; planking or wooden blocks supporting ship on sliding ways, previous to launch; steel washers fitted under the nut when bolting-up.

Pad Eye. An eye located on deck for fastening cables.

Panhead Rivet. A rivet with a pan-shaped head.

Panting. The in and out movement of shell plates at the bow of a ship, when at sea, due to water pressure when the ship is facing a heavy gale.

Panting Stringers. Fore-and-aft members on inside of shell at bow to prevent panting.

Passer. A man who passes rivets to the holder-on, and may put it in the rivet hole.

Passing Tongs. Tongs used in passing a rivet.

Pillar. Vertical member or column giving support to a deck. Also called stanchion.

Pintle. Fitting, or pin on the rudder which turns in a gudgeon.

Plan. A drawing prepared for use in building a ship.

Planking. Wood covering for decks, etc.

Platform. A partial deck.

Plating. The plates of the shell, a deck, a bulkhead, etc.

Poop. The after, upper portion of the hull, usually containing the steering gear.

Port. The left-hand side of the ship when facing the bow.

Porthole ("**Sidelight**"). A circular opening in the ship's side for light and air.

Propeller. Wheel consisting of two or more blades for propelling a ship.

Punch. A machine for punching holes in plates and angles.

Q

Quadrant. A fitting on the rudder head to which the steering chains are attached.

Quarter. A side of the stern.

Quarters. Living or sleeping rooms for officers and crew of a ship.

R

Rake. Slope of the bow when tilted forward. If the stem was built plumb, it would appear to tilt aft, because of the downward curve of the sheer.

Rabbet. A depression or offset designed to take some other adjoining part; as, for example, the rabbet in the stem to take the shell plating.

Rail. The upper edge of the bulwarks.

Reaming. Enlarging a rivet hole by means of a revolving cylindrical, slightly-tapered tool with cutting edges running along its sides.

Reverse Frame. An angle bar or other shape riveted to the inner edge of a transverse frame to reinforce it.

Ribband. A fore-and-aft wooden strip or heavy batten used to support the transverse frames temporarily after erection.

Rigger. Men hoisting material and doing rigging around the yard. Rigging ships with ropes and awnings, etc.

Rigging. Manila and wire ropes, lashings, etc., used to support masts, spars, booms. Also the handling and placing on board the ship of heavy weights and machinery.

Rise of Floor. The amount that the flat portion of the bottom of the ship rises from the keel to the side of the ship.

Rivet. A short steel bolt usually driven or clinched after being heated red hot.

Rivet Set. A tool used in caulking around a rivet.

Roll. Motion of the ship from side to side alternately raising and lowering each side of the deck.

Rose Box. Screen around the end of a bilge suction pump.

Rough or "Service" Bolt. Used to bolt a plate or frame to ship.

Rudder. A large fitting hinged to the rudder post. Used for steering the ship.

Rudder Post. The vertical post at after end of stern frame which supports rudder.

Rudder Stock. Shaft of rudder which extends up through ship and is connected to steering gear.

Rudder Stop. A fitting on rudder post to limit the swing of the rudder.

Run. Part aft of the bilge below and at the water line.

S

Sagging. Straining of the ship that tends to make the middle portion lower than the bow and stern.

Samson Post. A heavy vertical post that supports cargo booms.

Scantlings. The dimensions of various parts of the ship.

Scarph. To thin out a corner of a plate to allow for another plate to lap over it without extra thickness.

Screen Bulkhead. One that is dust tight only.

Scrieve Board. A large section of flooring in the mold loft in which the lines of the body plan are cut in with a knife. Used for making molds of the frames, beams, floor plates, etc.

Scupper. A drain from the edge of a deck discharging overboard.

Scupper Pipe. One which drains water from scuppers to side of ship.

Scuttle. A small hatch.

Seam. Fore-and-aft joint of shell plating.

Seam Strap. Butt strap of a seam.

Serving Board. A tool used in the same way as serving mallet.

Serving Mallet. A tool used in serving or wrapping cord about a rope or cable.

Set Iron. Bar of soft iron used on bending slab to give shape of frames.

Shaft. Long, round, heavy forging connecting engine and propeller.

Shaft Tunnel. Enclosed passage around propeller shaft extending from engine room to stern.

Shape. Long bar of constant cross-section, such as a channel, T-bar, angle-bar, etc.

Shears. Large machine for cutting plates and shapes.

Sheer. Fore-and-aft curvature of a deck.

Sheer Plan. Side elevation of a ship's outline.

Sheer Strake. The upper strake of shell plating, just below the bulwarks (at edge of deck).

Shell Expansion. A plan showing details of all plates of the shell.

Shell Landings. Places on the frames showing where the seams of shell plates come.

Shell Plating. The plates forming the outer skin of the hull.

Shore. A large wooden support or prop.

Shoulders, Bows. Where the bilge curve dies away. Both sides just aft of the stem. (Port bow—Starboard bow.)

Side. Portion of hull above the bilge.

Skylight. An opening in a deck to give light and air to the compartment below it.

Sliding Ways. (See Launching.)

Slop Chute. Chute for dumping garbage.

Smoke Stack. Large vertical funnel for passage of smoke from boilers.

Snap Rivet. A rivet driven with a snap die. (Has a round or button head and point.)

Sounding Pipe. Vertical pipe in oil or water tank used to measure depth of liquid in tank.

Spar. A long, round, wooden timber, or steel tube.

Spur Shore. A slanting brace on either side of ship or ways.

Stability. Tendency of a ship to remain upright.

Stage Bent. Upright support for staging.

Stanchion. An upright member used as a support.

Stapling. Collars, forged of angle bars, to fit around continuous members passing through bulkheads or decks for watertightness.

Starboard. The right-hand side of the ship when facing the bow (opposite to " port ").

Stay. A rope which stiffens and supports a mast or funnel, usually of steel.

Stealer. A strake of shell plating that is made extra wide to fit the width of two narrow strakes near the ends of the ship, where the girth is less.

Steering Gear. Apparatus for controlling the rudder.

Stem. Forging or casting forming extreme bow of ship, extending from keel to weather deck.

Step. To set in place as applied to a mast.

Stern. After end of ship.

Stern Frame. Large casting attached to after end of keel to form ship's stern. Often includes rudder post, stern post, and aperture for propeller.

Stern Tube. Tube in stern post through which propeller shaft passes.

Stiffener. An angle bar, T-bar, channel, etc., used to stiffen and form a support for plating of a bulkhead.

Stool. Support for shaft bearings.

Stopwater. A piece of packing of canvas and red lead or other material to prevent leakage where caulking is impractical.

Storm Valve. A check valve in a pipe opening above water line on a ship.

Stow. To put away securely.

Strake. A fore-and-aft course or row of shell or deck plating.

Stringer Plate. The outer strake of deck plating, as "main deck stringer." A fore-and-aft continuous member

used to give longitudinal strength. Others are made up of a narrow plate and angles, riveted to shell, cut out around frames, runs "continuous," and according to location are called "hold stringers," "bilge stringers," "side stringers."

Strong Back. Bar for locking cargo port doors and water-tight scuttles.

Strut. Support for propeller tail-end shaft used on boats with more than one propeller.

Superstructure. Deck houses, etc., above shelter deck.

Swash Plate. Plates in oil or water tank to prevent excessive movement of the liquid (form a baffle plate).

Symbols (marks of identification). Following partial list is illustrative:

V.K.FL.C.	Vertical keel floor clip.
FL.FR.	Floor frame.
FL.S.	Floor stiffener.
BE.FL.C.	Bilge bracket floor clip.
S.D.B.B.	Second deck beam bracket.
E.C.UDK.B.C.	Engine casing upper deck beam clip.
CK.	Countersink.
CK.T.S.	Countersink this side.
CK.O.S.	Countersink other side.

T

Tail Shaft. Short piece of propeller shaft extending through stern tube and carrying propeller.

Tank Top. Plating over the inner bottom.

Telegraph. Means of signaling from bridge to engine room.

Template. Full-sized pattern.

Thrust Block. Solid casting with rings which fit between rings on one section of the propeller shaft to take the thrust or pressure in a forward direction due to action of the propeller.

Tie Plate. Narrow plates attached to deck beams under wood deck to give extra strength.

Tiller. Arm attached to rudder head for operating rudder.

To Trim Ship. To shift ballast to make a ship change its position in the water.

Toggles. Wood timbers around which rope is knotted or fastened.

Tomahawk. A tool used in backing out rivets.

Transom. Rounded part of stern aft of the stern post.

Transom Frame. Aftermost main frame of ship attached to the stern framework; to which is attached the "cant frames."

Transverse. Athwartships, at right angles to the keel.

Transverse Frames. Athwartship members forming the ship's "ribs." (Above the floors.)

Trunk. Small casing passing between decks, such as is sometimes used for ladders.

Tumble Home. An inboard sloping of the ship's side above the level of greatest beam.

Tunnel Shaft. That part of the propeller shafting in the tunnel between the tail shaft and thrust block.

U

Uptake. Connection between boilers and smoke stack.

V

Ventilator. A device for furnishing fresh air to compartments below decks.

Vertical Keel. Row of plating extending vertically along center of flat plate keel. Sometimes called center keelson.

Voice Tube. Large speaking tube.

W

Warping Bridge. Bridge at after deck house used while docking a ship.

Water Line. The line of the water's surface when the ship is afloat.

Watertight. So riveted or caulked as to prevent the passage of water.

Water-tight Flat. Section of horizontal plating, across the bow or stern of a ship, usually made into a tank top.

Waterway. A narrow passage along the edge of the deck for the drainage of the deck.

Ways. Timbers, etc., on which a ship is built or launched. (See Launching.)

Weather Deck. A deck with no overhead protection.

Web. The vertical portion of a beam, the athwartship portion of a frame.

Web Frame. A frame with a deep web.

Welding. Making a joint of two metal parts by fusing more metal in between them.

Well ("Sump"). Space in bottom of ship into which waste water runs, that it may be pumped out.

Winch. A small hoisting engine.

Windlass. The machine used to hoist the anchors.

Y

Yard. A horizontal, athwartship spar fitted to a mast.

NOTE. We often speak of forward side and after side. It is, strictly speaking, incorrect, as it is the forward or after end; the other direction, at right angles, is port or starboard side, i.e., that part of a hatch nearest the bow is the forward end regardless of the size of the hatch.

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